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LIST OF CONTENTS.

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NOTICE OF ORDINARY GENERAL MEETING.

The SECOND ORDINARY GENERAL MEETING of the Twenty-Sixth Session of the Institution of Mining and Metallurgy has been fixed for THURSDAY, FEBRUARY 15TH, 1917, at **5.30** o'clock p.m., and will be held, by kind permission, at the Rooms of the Geological Society, Burlington House, Piccadilly, W.

The following Papers, copies of which will be issued with the February *Bulletin*, will be submitted for discussion:

The Wet Assay of Tin Concentrate.
By H. W. HUTCHIN, *Member.*

Hydraulic Tin Mining in Swaziland.
By J. JERVIS GARRARD, *Member.*

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the qualifications of Candidates for Admission into the Institution fulfil the requirements of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be open for Inspection at the Office of the Institution for a period of at least two months from the date of the Bulletin in which their applications are announced.

The following have applied for admission since December 14th, 1916:—

To MEMBERSHIP—

Gillio, Joseph John (*Congo Belge*).
Mack, Augustus Charles (*Kotchkar, Russia*).

To ASSOCIATESHIP—

Thomson, Robert (*R.E. Tunnelling Companies*).

To STUDENTSHIP—

Mosditchian, Hrand Sarkis (*Royal School of Mines, London*).

The following has applied for Transfer:—

To ASSOCIATESHIP—

Guttentag, Wilfred Emil (*London*).

MOVEMENTS OF MEMBERS.

Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. Ernest R. Bawden, Assoc. Inst. M.M., has left England for Nigeria.

Mr. John A. Dennison, M. Inst. M.M., has left England for the Transvaal.

Mr. Edgar L. Edmonds, Assoc. Inst. M.M., has left England for Northern Nigeria.

Mr. George H. Foster, Assoc. Inst. M.M., is returning to England from Borneo.

Mr. J. T. Keating, M. Inst. M.M., has left England for the Gold Coast.

Mr. W. Perring, Assoc. Inst. M.M., is returning to England from Northern Nigeria.

Mr. J. Henry Rickard, M. Inst. M.M., has recently returned to England from the United States.

Mr. R. A. Rusha, Assoc. Inst. M.M., has left England for Bolivia.

Mr. W. J. C. Scrutton, Assoc. Inst. M.M., has returned to England from Venezuela.

Mr. Ernest R. Woakes, M. Inst. M.M., has left England for South America.

ADDRESSES LOST.

F. B. Bradshaw, P. R. Hudson, O. L. de Lissa, D. Nicholas, L. G. Ray, and J. F. Richards.

INDEX OF RECENT BOOKS.

NOTE.—Books marked with an asterisk are contained in the Library of the Institution.

ANALYSIS OF COPPER: ITS ORES AND ALLOYS. G. L. Heath. New York: McGraw-Hill Book Company. $3.

*COPPER RECOVERY FROM ITS ORES BY LEACHING AND PRECIPITATION, IN THE UNITED STATES. J. D. Connor. Adelaide: South Australia Department of Mines.

*GEOLOGICAL MAP OF MYSORE. Bangalore: Department of Mines and Geology, Mysore State.

HANDBOOK OF ROCK EXCAVATION METHODS AND COSTS. H. P. Gillette. New York: Clark Book Company. $5.

*INVESTIGATION OF THE COALS OF CANADA WITH REFERENCE TO THEIR ECONOMIC QUALITIES. Extra Volume. — WEATHERING OF COAL. J. B. Porter. Ottawa: Canada Department of Mines, Mines Branch.

*MINERAL RESOURCES OF MYSORE. W. F. Smeeth and P. S. Iyengar. Bangalore: Department of Mines and Geology, Mysore State. 3 *rupees*.

*MINERAL RESOURCES OF THE UNITED STATES IN 1915. Gold, Silver, Copper, Lead and Zinc in New Mexico and Texas, by C. W. Henderson. Gold, Silver, Copper, Lead and Zinc in Utah, by V. C. Heikes. Washington, D.C.: United States Geological Survey.

*REVIEW OF MINING OPERATIONS IN THE STATE OF SOUTH AUSTRALIA FOR THE HALF-YEAR ENDED JUNE 30TH, 1916. Adelaide: South Australia Department of Mines.

*SYNOPSIS OF RULES AND ORDERS RELATING TO THE EXPLOITATION OF MINERALS IN MYSORE. M. Varadaiya. Bangalore: Department of Mines and Geology, Mysore State. 1 *rupee*.

INDEX OF RECENT PAPERS.

NOTE.—All Papers indexed may be consulted in the Library of the Institution.

ANALYSIS & CHEMISTRY.

British Coal-Tar Colour Industry and its difficulties in time of war. C. M. Whittaker. —Journal, Royal Society of Arts, London, Vol. 65, December 8, 1916, pp. 61-72. *6d.*

Copper Leaching Test Plant at Winona.— Engineering and Mining Journal, New York, Vol. 102, November 25, 1916, pp. 929-30. *15c.*

Experiments on the Concentration of Radium in Carnotite Ores. A. G. Loomis and H. Schlundt. —Journal of Industrial and Engineering Chemistry, New York, Vol. 8, November, 1916, pp. 990-6. *50c.*

COAL.

British Coal-Tar Colour Industry and its difficulties in time of war. C. M. Whittaker. —Journal, Royal Society of Arts, London, Vol. 65, December 8, 1916, pp. 61-72. *6d.*

Coal Mining in North Borneo. (*Paper read before the National Association of Colliery Managers.*) **W. Hopwood.**—Iron and Coal Trades Review, London, Vol. 93, December 1, 1916, pp. 674-5. *6d.*

Coedley Colliery, Glamorganshire.— Iron and Coal Trades Review, London, Vol. 93, December 8, 1916, pp. 693-5. *6d.*

Cost of Coal. (*Paper read before the American Mining Congress, November, 1916.*) **G. O. Smith and C. E. Lesher.**—Metallurgical and Chemical Engineering, New York, Vol. 15, December 1, 1916, pp. 681-5. *25c.*

Economical Production and Utilization of Power at Collieries. F. F. Mairet.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 71-116; 127-40. *6s.*

Hurlet Sequence and the base of the Carboniferous Limestone series in the districts of Campsie and Kilsyth. D. Ferguson.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 7-32. *6s.*

Prospects of the Carbonization of Coal with By-product recovery as a South African Industry. S. B. Bilborough.— Journal, South African Institution of Engineers, Johannesburg, Vol. 15, November, 1916, pp. 58-69. *2s.*

Structure of the South Staffordshire Coalfield, with special reference to the concealed areas in the neighbouring fields. E. A. Newell Arber.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 35-70. *6s.*

COAL—*continued.*

Udi-Okwoga Coalfield of Southern Nigeria. —Bulletin of the Imperial Institute, Vol. 14, July-September, 1916, pp. 369-78. *2s. 6d.*

Widening the Upcast Shaft at Tinsley Park Colliery. H. J. Atkinson.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 117-26. *6s.*

Working out the Pillars at the Mohpani Mines by means of Packing; and a comparison of the Wet and Dry Systems of Packing. F. L. G. Simpson.—Transactions, Mining and Geological Institute of India, Calcutta, Vol. 11, Part 1, October, 1916, pp. 29-48. *4s.*

COPPER.

Britannia Mine and Mill. T. A. Rickard. —Mining and Scientific Press, San Francisco, Vol. 113, November 11, 1916, pp. 693-700. *10c.*

Copper Leaching Test Plant at Winona.— Engineering and Mining Journal, New York, Vol. 102, November 25, 1916, pp. 929-30. *15c.*

Cupro-Nickel: its micro-structure. J. Scott. —Metal Industry, London, Vol. 9, December 15, 1916, pp. 675-6. *4d.*

Electrolytic Copper Refining.—Engineering and Mining Journal, New York, Vol. 102, November 11, 1916, pp. 874-6. *15c.*

Electrolytic Refining of Copper. (*Paper read before the American Institute of Metals.*) **F. L. Antisell and S. Skowronski.**—Metal Industry, London, Vol. 9, December 1, 1916, pp. 622-4. *4d.*

Influence of Arsenic on Copper. F. Johnson.—Metal Industry, London, Vol. 9, December 8, 1916, pp. 648-52. *4d.*

Mount Mudie Copper Mine, Kilkivan district, Queensland. E. C. Saint-Smith.— Queensland Government Mining Journal, Brisbane, Vol. 17, October 14, 1916, pp. 480-3. *6d.*

Pinar del Rio Copper region, Cuba. R. H. Vail.—Engineering and Mining Journal, New York, Vol. 102, November 25, 1916, pp. 960-2. *15c.*

ECONOMICS OF MINING AND METALLURGY.

Cost of Coal. (*Paper read before the American Mining Congress, November, 1916.*) **G. O. Smith and C. E. Lesher.**—Metallurgical and Chemical Engineering, New York, Vol. 15, December 1, 1916, pp. 681-5. *25c.*

INDEX OF RECENT PAPERS—*continued.*

ECONOMICS OF MINING AND METALLURGY—*continued.*

Economic development of Russia and Britain's interest therein. L. Urquhart.—Journal, Royal Society of Arts, London, Vol. 65, November 24, 1916, pp. 28-37. 6*d*.

Estimating Construction Costs. F. W. Foote.—Engineering and Mining Journal, New York, Vol. 102, November 11, 1916, pp. 857-60. 15*c*.

Excerpts from Mr. Justice Eve's Judgment in the Globe and Phœnix case.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 343-7. 1*s*.

Excess Profits Tax.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 314-15. 1*s*.

Extra-lateral Right: shall it be abolished? W. E. Colby.—Mining and Scientific Press, San Francisco, Vol. 113, November 11, 1916, pp. 701-4. 10*c*.

Miners' Phthisis prevention. A. Cooper Key.—Engineering and Mining Journal, New York, Vol. 102, November 18, 1916, pp. 898-90. 15*c*.

Reducing Air-Drill Repair Costs. F. Ayer.—Engineering and Mining Journal, New York, Vol. 102, November 11, 1916, pp. 864-6. 15*c*.

Standardization and the Metric System.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 319-20. 1*s*.

Standardization and the Metric System. (*Discussion at an informal General Meeting of the Institution of Mining and Metallurgy, held November 16, 1916.*)—Bull. No. 147, Institution of Mining and Metallurgy, December 14, 1916.

Valuation of Bedded Mineral Land. F. A. Grugnon.—Engineering and Mining Journal, New York, Vol. 102, December 2, 1916, pp. 969-71. 15*c*.

GEOLOGY AND ORE DEPOSITS.

Economic Geology of the Insizwa Range. W. H. Goodchild.—Bull. No. 147, Institution of Mining and Metallurgy, December 14, 1916.

Faulting in St. Agnes district, Cornwall. J. B. Fern.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 341-2. 1*s*.

Geology of the Shamva Mine.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 337-41, G. S. Corstorphine; pp. 348-9, F. P. Mennell. 1*s*.

Hurlet Sequence and the base of the Carboniferous Limestone series in the districts of Campsie and Kilsyth. D. Ferguson.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 7-32. 6*s*.

GEOLOGY AND ORE DEPOSITS—*continued.*

On Ore Deposits. F. B. Ely.—Mining and Scientific Press, San Francisco, Vol. 113, November 11, 1916, pp. 689-91. 10*c*.

Structure of the South Staffordshire Coalfield, with special reference to the concealed areas in the neighbouring fields. E. A. Newell Arber.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 35-70. 6*s*.

GOLD.

Geology of the Shamva Mine.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 337-41, G. S. Corstorphine; pp. 348-9, F. P. Mennell. 1*s*.

Gold Dredging in Yukon.—Canadian Mining Journal, Toronto, Vol. 37, November 15, 1916, pp. 535-45. 15*c*.

Greatest Gold Mine.—Mining and Scientific Press, San Francisco, Vol. 113, November 4, 1916, pp. 654-6. 10*c*.

Milling of Gold Ores. J. McCombie.—Mining and Engineering Review, Sydney and Melbourne, Vol. 9, October, 1916, pp. 8-9. 6*d*.

METALLURGY (General).

Analysis of Tank Resistance in Electrolytic Refining. L. Addicks.—Metallurgical and Chemical Engineering, New York, Vol. 15, November 15, 1916, pp. 566-71. 25*c*.

Nevada Wonder Mill. A. C. Daman.—Engineering and Mining Journal, New York, Vol. 102, November 25, 1916, pp. 927-8. 15*c*.

Precipitation on Zinc dust. F. Danvers Power.—Mining and Engineering Review, Sydney and Melbourne, Vol. 9, October, 1916, pp. 10-11. 6*d*.

Reclamation of Brass Ashes. A. F. Taggart.—Metal Industry, London, Vol. 9, November 24, 1916, pp. 597-9. 4*d*.

MILLING & CONCENTRATION.

Advancement and present status of Preferential Flotation. H. J. Stander.—Mining and Engineering World, Chicago, Vol. 45, November 18, 1916, pp. 861-4. 10*c*.

Elmore Flotation Process. A. S. Elmore.—Mining and Scientific Press, San Francisco, Vol. 113, November 18, 1916, pp. 725-7. 10*c*.

Importance of efficient settling of Slime. P. W. Avery.—Mining and Scientific Press, San Francisco, Vol. 113, November 18, 1916, pp. 738-42. 10*c*.

INDEX OF RECENT PAPERS—*continued.*

MINING (General).

American Mining Congress; Chicago Meeting, November 13-16, 1916. — Mining and Engineering World, Chicago, November 25, 1916, pp. 906-15; 919-22. 15c.

Cyclometer Surveys. L. H. Ower. — Proceedings, Australasian Institute of Mining Engineers, Melbourne, No. 23, September 30, 1916, pp. 103-13. 4s.

Journey to British Columbia. T. A. Rickard.—Mining and Scientific Press, San Francisco, Vol. 113, November 4, 1916, pp. 657-64. 10c.

Measuring with the Steel Tape in Mine Surveying. W. S. Weeks. — Mining and Scientific Press, San Francisco, Vol. 113, November 4, 1916, pp. 668-70. 10c.

Mining districts of the state of Washington. R. B. Brinsmade. — Mining and Scientific Press, San Francisco, Vol. 113, November 18, 1916, pp. 743-5. 10c.

Morococha and Casapalca districts in Peru. J. T. Singewald, Junr., and B. L. Miller.— Engineering and Mining Journal, New York, Vol. 102, November 18, 1916, pp. 889-93. 15c.

Prospector's Field Work. H. Lang. — Mining and Scientific Press, San Francisco, Vol. 113, November 11, 1916, pp. 705-6. 10c.

Testing Mine Rescue Apparatus. C. E. Pettibone.—Engineering and Mining Journal, New York, Vol. 102, December 2, 1916, pp. 985-7. 15c.

Trip through Honduras. D. McBride.— Engineering and Mining Journal, New York, Vol. 102, November 11, 1916, pp. 851-4. 15c.

Widening the Upcast Shaft at Tinsley Park Colliery. H. J. Atkinson.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 117-26. 6s.

MINOR METALS.

Aluminium, Alumina and Alum deposits of Queensland. B. Dunstan. — Queensland Government Mining Journal, Brisbane, Vol. 17, October 14, 1916, pp. 475-8. 6d.

Cupro-Nickel: its micro-structure. J. Scott. — Metal Industry, London, Vol. 9, December 15, 1916, pp. 675-6. 4d.

Effect of Cadmium in Alloys. G. C. Stone. —Engineering and Mining Journal, New York, Vol. 102, November 18, 1916, pp. 909-10. 15c.

Experiments on the Concentration of Radium in Carnotite Ores. A. G. Loomis and H. Schlundt.—Journal of Industrial and Engineering Chemistry, New York, Vol. 8, November, 1916, pp. 990-6. 50c.

MINOR METALS—*continued.*

Developments in the Tungsten Industry.— Mining Journal, London, Vol. 115, November 25, 1916, pp. 777-8. 6d.

Influence of Arsenic on Copper. F. Johnson.—Metal Industry, London, Vol. 9, December 8, 1916, pp. 648-52. 4d.

Manganese Ores of Bukowina. (*Excerpt of paper read before the Iron and Steel Institute, September, 1916.*) H. K. Scott.—Engineering and Mining Journal, New York, Vol. 102, November 25, 1916, pp. 935-7. 15c.

Manufacture of Tungsten Powder at the works of High-Speed Alloys, Ltd., Sheffield. —Iron and Coal Trades Review, London, Vol. 93, November 24, 1916, p. 636. 6d.

Melting of Platinum. C. M. Hoke.—Metal Industry, London, Vol. 9, December 1, 1916, pp. 613-15. 4d.

Occurrence and Utilisation of Antimony Ores.—Bulletin of the Imperial Institute, Vol. 14, July-September, 1916, pp. 389-417. 2s. 6d.

Occurrence and Utilisation of Cobalt Ores. —Bulletin of the Imperial Institute, Vol. 14, July-September, 1916, pp. 417-37. 2s. 6d.

Sedimentary Magnesite deposit, near Bissell, California. L. A. Palmer. — Engineering and Mining Journal, New York, Vol. 102, December 2, 1916, pp. 965-7. 15c.

Tungsten manufacture in Great Britain.— Chemical Trade Journal, London, Vol. 59, December 9, 1916, p. 507. 4d.

NON-METALLIC MINERALS.

Graphite.—Mining Journal, London, Vol. 115, December 2, 1916, pp. 793-4. 6d.

Monazite and other Thorium minerals in Ceylon.—Bulletin of the Imperial Institute, Vol. 14, July-September, 1916, pp. 321-69. 2s. 6d.

Potash-bearing minerals of California. H. Lang. — Mining and Scientific Press, San Francisco, Vol. 113, November 4, 1916, pp. 665-7. 10c.

Testing Refractory Firebrick.—Engineering and Mining Journal, New York, Vol. 102, December 2, 1916, pp. 967-8. 15c.

Texture of Firebricks. (*Part of discussion on "Refractory Materials" before the Faraday Society.*) J. W. Mellor.—Metal Industry, London, Vol. 9, December 15, 1916, pp. 677-9. 4d.

PETROLEUM.

Norfolk Oil Shales. (*Paper read before the Institution of Petroleum Technologists.*) W. Forbes-Leslie.—Colliery Guardian, London, Vol. 112, November 3, 1916, pp. 853-5. 5d.

INDEX OF RECENT PAPERS—*continued.*

PLANT AND POWER.

Economical Production and Utilisation of Power at Collieries. F. F. Mairet.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 1, 1916-17, pp. 71-116; 127-40. 6s.

Electric Shovel at Granby Mine, Phœnix, British Columbia. C. M. Campbell.—Engineering and Mining Journal, New York, Vol. 102, December 2, 1916, p. 979. 15c.

Estimating Construction Costs. F. W. Foote.—Engineering and Mining Journal, New York, Vol. 102, November 11, 1916, pp. 857-60. 15c.

Reducing Air-Drill Repair Costs. F. Ayer.—Engineering and Mining Journal, New York, Vol. 102, November 11, 1916, pp. 864-6. 15c.

Triplex Pumps in Wisconsin Zinc Mines.—Mining and Engineering World, Chicago, Vol. 45, November 11, 1916, p. 829. 10c.

SILVER.

Nevada Wonder Mill. A. C. Daman.—Engineering and Mining Journal, New York, Vol. 102, November 25, 1916, pp. 927-8. 15c.

TIN.

Bucket-Dredging for Tin in the Federated Malay States. H. D. Griffiths.—The Mining Magazine, London, Vol. 15, December, 1916, pp. 327-36. 1s.

Cornish Tin and Tungsten Research. W. H. Trewartha-James.—The Mining Magazine, London, Vol. 15, December, 1916, p. 349. 1s.

ZINC.

Bisulphite Process for extracting Zinc.—Engineering and Mining Journal, New York, Vol. 102, November 18, 1916, pp. 895-8. 15c.

Spencerite, a new Zinc Phosphate from British Columbia. T. L. Walker.—Mineralogical Magazine, London, Vol. 18, No. 83, November, 1916, pp. 76-81. 5s.

Triplex Pumps in Wisconsin Zinc mines.—Mining and Engineering World, Chicago, Vol. 45, November 11, 1916, p. 829. 10c.

Zinc mines of Tonkin.—Engineering and Mining Journal, New York, Vol. 102, November 18, 1916, pp. 900-2. 15c.

MILITARY SERVICE.

SUPPLEMENTARY LIST.

The following have been notified since the issue of the last Bulletin, December 14th, 1916:

MEMBERS SERVING WITH H.M. FORCES.

Davey, J., Royal Engineers, (2nd Lieut.).

Greatwood, H., Royal Field Artillery, (2nd Lieut.).

Hargreaves, E. P., Australian Engineers, (2nd Lieut.).

Home, D. R., Royal Engineers, (Lieut.).

Liddelow, C. C. W., Malay States Volunteer Rifles.

Macnutt, C. H., Canadian Engineers, (Lieut.).

Panchaud, C. A., Malay States Volunteer Rifles.

Rickard, R. E., Canadian Engineers.

Salmon, F. J., Royal Engineers, (Captain).

Williams, M. J., Royal Engineers.

PROMOTIONS OR OTHER CHANGES.

Brown, A. O., Royal Engineers, (2nd Lieut.).

Fraser, The Hon. A. J., Lovat Scouts, (Major).

McClure, G. B., Royal Highlanders (Black Watch), (Captain).

Moore, R. I., Australian Imperial Forces, (Lieut.–Staff Captain).

Nissen, P. N., Sherwood Foresters, (Major).

Pearson, A., Royal Engineers, (Captain).

Swinney, L. A. E., Royal Engineers, (2nd Lieut.).

Vallentine, E. J., Aeronautical Inspection Department, (Lieut.)

KILLED IN ACTION.

James Cowie Simpson, *Associate*, 2nd Lieut., Royal Engineers. (*In France, December 5th, 1916.*)

George Herbert Milton, *Student*, 2nd Lieut., Royal Field Artillery. (*In France, October 25th, 1916.*)

Colin Johnstone Maclaverty, *Associate*, Captain, King's Shropshire Light Infantry. (*In France, September 16th, 1916.*)

Crowther & Goodman, Ltd., Printers, 124, Fenchurch Street, London, E.C.

THE INSTITUTION OF MINING AND METALLURGY.

TWENTY-SIXTH SESSION, 1916-1917.

FIRST GENERAL MEETING,

Thursday, December 21st, 1916.

Held at the Rooms of the Geological Society, Burlington House, Piccadilly, W.

MR. EDGAR TAYLOR, *President*, in the Chair.

DISCUSSION
ON
'The Economic Geology of the Insizwa Range,'

By W. H. GOODCHILD, *Member*.

Mr. W. H. Goodchild, in introducing the paper, exhibited and described a series of lantern slides. Among these were a number of geological sections and plans illustrating the peculiar curved outlines of the intrusions in the Mount Ayliff district; their habit of cutting across the sedimentary rocks without disturbing the horizontality of the stratification planes; the manner in which the picrite differentiate occurs as central tapering masses in the thicker portions of the sheets, the masses being surrounded by olivine gabbro or some more acid variety of gabbro; the structure of the Insizwa Range at several widely separated points and, for comparison, the general form and structure of the somewhat similar Tabankulu Range. Slides of the undulatory sheets on the Queenstown district of South Africa were shown illustrating the morphological similarity of these to the intrusions in the Mount Ayliff district.

A number of slides were also shown amplifying the petrographical sections of the paper and a figure taken from Bowen's paper on 'Crystallization Differentiation in Silicate Liquids' illustrating

the early formation of olivine crystals and the sinking of these in the fused silicate liquid, thus firmly establishing on a strong experimental basis the view that the analogous structures shown in the field are primarily a result of crystallization differentiation *in situ* during the cooling of the magma.

The origin of the basin shape, concerning which he had put forward the suggestion that the undulatory character of the sheets resulted from the sediments being in but a partially consolidated state at the time of injection, was a section introduced into the paper more on account of the possibly wider economic interest of the subject than of any special bearing on the specific economic prospects of the Insizwa Range. It was a matter of wide interest since argillaceous sediments are by far the most common type of sedimentary formation, and it had been estimated by such an authority as Dr. F. W. Clarke, that some 80 per cent. of the world's sedimentary rocks are argillaceous. In South Africa alone, the Karroo beds, in which many examples of these peculiar undulatory injections are already known, cover an area of not less than a quarter of a million square miles. The tendency towards central concentration of the ore minerals in the basins, coupled with the fact that it is these parts of the sheets that, generally speaking, tend to persist after the other parts have been removed by erosion, suggests the possibility of the existence of hidden orebodies of magnitude in situations where their occurrence might otherwise not be suspected. This aspect of the question invests the problem of the causes of the undulatory character of the sheets with a practical interest for the economic geologist that it would not perhaps otherwise possess.

Similarly, too, small microgranite veins are quite a common feature of the contact zone of basic injections into argillaceous sediments, and their mode of origin and relationship to the mineralized or unmineralized portions of differentiated sheets, is a matter of more than local interest.

He would mention a mineralogical curiosity, viz., that in the contact veins there sometimes occurred little grains of metallics embedded in the sulphides. These grains were composed of about two-thirds nickel, 5 to 6 per cent. copper and iron, and the balance was principally gold and silver. It was a naturally occurring alloy to which he could find no parallel anywhere else. The nearest approach appeared to be some grains of so-called amalgam of nickel, gold and silver reported as occurring in some alluvials in Santo Domingo, but whence these grains were derived no one seemed to know, and there was very little information available

concerning them. The comparison between the two occurrences seemed to him to be sufficiently suggestive to be worth recording.

The sulphide veins showed the most extraordinary variations in their contents, and how these variations were brought about was a complex geo-chemical problem of great interest, having regard to the collateral evidence as to their general mode of origin. He would mention that a sample of sulphide ore recently assayed ran close upon 6 oz. gold, 4 oz. platinum, and about $1\frac{1}{4}$ oz. palladium per ton. How the platinum occurred he had so far been unable to determine. It appeared to be in a different state from the platinum in the Sudbury ores. He concluded by saying that there was nothing more than a distant geological similarity between the Insizwa and Sudbury occurrences, although Insizwa had on several occasions been dubbed 'The Sudbury of South Africa.'

Mr. T. Crook said he was sure that Mr. Goodchild's paper would be welcomed by all students of ore-genesis as a very useful account of the nickeliferous pyrrhotite deposits of the Insizwa Range. The paper was one that had evidently involved a great deal of painstaking labour and careful study, and contained a lot of very interesting petrological detail.

The more important features of the data given by Mr. Goodchild had already been given by Dr. du Toit of the Union Geological Survey, who had written good accounts of the general and economic geology of the Insizwa Range and the neighbouring areas in this part of the Cape Province. As regards the main features of the petrology of the sills of this area, Mr. Goodchild appeared to be in agreement with Dr. du Toit. The points of difference were points of comparatively unimportant detail from an economic standpoint, except that Dr. du Toit, though not by any means pessimistic as regards future mining possibilities, was less buoyantly hopeful than Mr. Goodchild. Mr. Goodchild seemed to be quite positive in his view that there would be an accentuation of the ore-bearing picrite zone towards and at the middle of the basin.

This optimistic view was based on the theory that the nickeliferous pyrrhotite had arisen by a process of segregation along the floor of the sill during the crystallization of the norite magma, and that the particular process involved was one of differentiation after intrusion. According to this theory the igneous matter of the sill was injected in a homogeneous fluid state, and during cooling, the olivine and ore minerals, which separated out first, settled, by virtue of their higher density, towards the base of the sill. Mr. Goodchild added the further inference that the basin-shaped depression, which developed contemporaneously with the intrusion, allowed the ore-

minerals to gravitate towards the middle of the depression, where they might therefore be expected to form a thicker and richer mass of ore than was to be found around the edge of the basin. It should be pointed out, however, that Mr. Goodchild assumed rather than proved that the warping of the shale beds preceded differentiation.

With reference to the general question of magmatic segregation, Mr. Goodchild's paper appeared at an opportune moment, seeing that there had recently been a revival of the controversy with regard to the origin of the nickeliferous pyrrhotite deposits of Sudbury in Ontario. For many years it had been the predominant view that the Sudbury deposits owed their origin to segregation from a norite magma, and this view had been and still was held very widely with reference to deposits in other parts of the world. It rested on a formidable array of tectonic and petrological evidence of a strongly convincing character; and the arguments based on microscopical observations, that were brought against it some years ago, were altogether too weak to overthrow it. Even admitting, as had been recently claimed, that the granitic floor of the Sudbury norite stood in intrusive relation to the latter in some places, it did not follow that the orebodies did not arise by segregation from the norite magma. It might well be that the ore deposits owed some of their peculiarities to later granitic intrusions, but it was difficult to believe that these intrusions brought the ore with them.

In considering the Sudbury case, one did well to keep in view the noritic orebodies of nickeliferous pyrrhotite occurring in other parts of the world. There was a petrological family likeness among them, and the evidence of magmatic segregation from a norite magma seemed on the whole to be conclusive. In the Insizwa instance, at any rate, the conditions appeared to have been comparatively simple, and it was difficult to see what reasonable alternative there could be to this theory.

When, however, they came to consider exactly how the differentiation took place, there was perhaps room for some difference of opinion. One might reasonably decline to accept the view that the process had been one of gravitative differentiation from a sill of magma injected in a homogeneous condition. What was the exact meaning of the band of picrite 500 ft. above the base of the sill? What about the flow-banding which Mr. Goodchild openly admitted? The sharp demarcation between the picrite and norite was suggestive of an explanation different from that given by Mr. Goodchild. There appeared to be nothing like a regular increase in basicity towards the floor of the sill, and the irregularities appeared to be too serious to

favour the theory of differentiation from a magma injected in a homogeneous condition. Moreover, the relation of the picrite zone to the norite and hornfels seemed to be of a transgressive character in places; and there appeared to be evidence in some parts of these Pondoland basins that the picrite did not floor the whole of the basins.

On these considerations it seemed possible, or even likely, that the magma of the Insizwa sill was heterogeneous, i.e., in some measure already differentiated, at the time of injection. It seemed possible that the picrite might have been injected at a later stage than the main mass of the sill. Even if this be denied for the sill as a whole, it might still be true of any given part of the sill, since the picrite layer might have been affected by movement during the last stages of consolidation. These possibilities merited discussion, since they obviously had an important bearing on the question of ore-potentialities discussed by Mr. Goodchild.

It was not necessary to assume that sills and laccolites gaped as the result of only one stage of movement. Much of the evidence available concerning the petrology of sills indicated that they had opened up in a series of stages, and that the process of intrusion had covered a long-enough period to allow of differentiation before or during injection.

With regard to the condition of the hornfels beds just prior to intrusion, he (Mr. Crook) was inclined to agree with Dr. du Toit that they were probably in the condition of shales rather than wet clays, since the nature and extent of the metamorphism suggested that they were buried at considerable depth at the time of intrusion. At least they had probably suffered from a considerable measure of compacting prior to the intrusion of the norite, and Mr. Goodchild's estimate of their porosity seemed to be rather excessive. For that reason he (Mr. Crook) could not agree with Mr. Goodchild that the volume relation of the sills to the shale beds had anything to do with the porosity of the shales prior to intrusion.

Mr. Goodchild's views on the origin of the microgranite veins were very interesting, but he (Mr. Crook) found it hard to believe that these microgranites were fusion products. If, in spite of the fact that it contained the fluxing ingredients referred to, the hornfels did not melt when the magma was exerting its full thermal effect, why should it melt after the magma had become consolidated? He agreed with Mr. Goodchild that the assimilation of the hornfels, and subsequent differentiation, was perhaps not the best explanation of the mode of formation of these veins. But he felt sceptical towards

the view that they were products of 'supermetamorphism' by fluxing action. It seemed much more probable that they were due to exudation of solutions during the last stage of cooling. Indeed, Mr. Goodchild's views as to the absence of solution phenomena, both as regards the microgranite and the sulphide veins, seemed rather extreme, and it would be interesting to know exactly what had driven him to the conclusion that fluxing of the sulphides and the hornfels was necessary to explain the origin of these veins.

The absence of the cobalt estimations in the analyses given by Mr. Goodchild was a noticeable feature. Did this mean that cobalt was absent, or was any cobalt that might be present included in the nickel percentages given?

The platinum question was one of importance from the economic point of view, and one on which it would be useful to have more details. If he remembered rightly, flotation experiments had been carried out on the ore, and it had been found that the platinum did not concentrate with the sulphides. Had that result been confirmed? If so it seemed to be a serious matter from an economic standpoint. He would like to know if any matte-smelting experiments had been carried out, and, if so, what results had been obtained as regards the recovery of platinum, palladium and other possible by-products. Any information that might be available as to the results of mechanical concentration trials would be of great interest.

With reference to the behaviour of the compass-needle in certain areas where its violent agitation might be due to hidden masses of pyrrhotite, it might be well to keep in mind the fact that basic igneous rocks sometimes showed strong magnetic polarity, presumably owing to the presence of magnetite disseminated in an orderly manner through the mass of the rock; and small as appeared to be the amount of magnetite in the Insizwa rocks generally, the possibility of slight local segregation of this mineral could not be ignored.

It mattered little perhaps, from an economic standpoint, what view one took as to the causes that led to the intrusion of these immense basic masses in the Karroo beds of Pondoland and other parts of South Africa; but it might be doubted if the melting of 'the South African ice cap' furnished an adequate cause. Many would prefer to think that the superficial agencies involved were of a much more complex character, and that they were further complicated by interplay with agencies operating deep-seatedly and independently during the break-up of the Gondwanaland continent. At any rate the effect of these agencies probably spread far beyond the limits of South Africa, and compared with the huge earth-

waves to which they gave rise, the effect of the melting of an ice cap must have been a mere ripple.

Mr. Goodchild was to be congratulated on the comprehensive way in which he had tackled the problems presented by these Insizwa deposits. There was clearly need of continuous petrological work in connexion with mining development in deposits of this character, and if this development was to proceed successfully in the Insizwa area, it seemed necessary that the economic importance of petrological work, such as that presented in Mr. Goodchild's paper, should be fully recognized.

Mr. J. Morrow Campbell said that many members must be pleased that the author had given such an able description of a most interesting deposit. The paper was of a type which many would like to see multiplied in the records of the Institution. Quite apart from the work which had been done in the field, it was only people who had done petrological work who knew the vast amount of labour which the paper must have involved in the laboratory subsequent to the field work.

He had not many remarks to make, but the author's explanation of the basin-like form of the Insizwa gabbro sheet seemed to him somewhat bold. The thickness was given as something under 2000 ft. to over 3000 ft. Its average dip inwards at the outer contact was given at 30°; but the total depth of the inside of the basin above its edges was not stated.

On p. 6 the author stated: 'It thus stands in a cross-cutting relation to the bedding planes of the encasing sedimentary rocks, and is not truly laccolithic in origin.' Did its variation from a true laccolite consist in the intrusion cross-cutting the sedimentaries and not passing laterally along the bedding planes? That was not explained. True laccolites were typically lenticular in form, and one could not reasonably expect them to be otherwise. Such an assumption as the author's had not been considered necessary to explain what practically required no explanation, viz., the convex form of the lower surface of a laccolite.

The compressibility of the underlying sediment, owing to lack of rigidity at the time of the intrusion, seemed to be assumed without adequate evidence, especially if the sheet was not truly laccolithic in origin.

On p. 27 that argument was followed up by the assertion that the total thickness of the sheet corresponded to the contraction in volume that would result from the compression of the total thickness of the beds in the Ecca and Beaufort series on the basis of the average porosity of clay.

He did not know the thickness of those series, but on the basis of the author's figures and the quotation from Mr. du Toit on p. 27, they must amount to from 6000 to 10,000 ft. in thickness. Was it reasonable to suppose that that great thickness could be compressed to its maximum possible extent during the period of intrusion of the gabbro? That that period of intrusion was not very prolonged must be assumed from what the author said on p. 26: 'The evidence does not seem to point to any very extensive assimilation of the invaded sediments by the magma, but a limited amount of marginal assimilation is indicated.'

A highly basic rock intruded very slowly into a zone of decidedly acid sediments would undoubtedly assimilate much of the latter. The general presence of hydrous silicates in the hornfelses in the neighbourhood of the intrusive could hardly be regarded as giving any support to the theory that the clays were not consolidated at the time of the intrusion, because all such sedimentary strata, even when consolidated, contained quite enough water to account for the formation of hydrous silicates under such conditions.

The author's assumption of magmatic segregation under low pressure conditions rendered it difficult to accept his theory of hydrostatic head and plastic sediment in explanation of the basin formation. A great mass of superincumbent strata with high intrusive pressure might be more convincing.

The evidence adduced regarding the order of crystallization of the sulphides in the Insizwa gabbro, which showed it to be a reversal of the order that had been proved both in the Norwegian and Canadian deposits, was most interesting, but he was afraid it only served to make them doubt the extent of their knowledge of the behaviour of molten magmas on solidification.

In pegmatite, tourmaline was supposed to separate first, and usually did so, yet he had seen a well-formed quartz crystal partly enclosed within a large tourmaline crystal.

As the author had brought a considerable amount of evidence to support his assumption that the magmatic segregation took place under comparatively low pressure and, therefore, at only shallow depth, it was as well to take notice of the fact mentioned on p. 18 that in a hornfels collected by Mr. du Toit blue tourmaline was found. That would point rather to cooling at considerable depth.

Again, on p. 18, biotite was said to abound in the hornfelses and white mica was also found. Micas were characteristic of rocks cooling at considerable depth under pressures sufficient to prevent the water which was essential to their formation being given off.

Of course, the depth already given might have been sufficient for that purpose, but it was almost certain that it would not be sufficient to promote the formation of tourmaline. In the matter of gravitative segregation, when one came to consider the enormous thickness, certainly up to an average of 2000 ft., and being as much as 3000 ft., they found in the upper part of the deposit no olivine, and as they approached the lower parts they found large quantities of olivine. That was supposed to have segregated and gravitated during the period in which that rock was in a molten condition *in situ*. It seemed to him somewhat a large order for crystals of that description to sink that enormous depth, and the fact that that length of time was demanded for such a purpose was rather contradicted by the period in which the absorption of the surrounding sedimentaries took place.

There was also a minor matter. On p. 31 he found the statement that the rate of sinking of a crystal in a molten magma was directly proportional to the square of its semi-diameter. Why 'semi-diameter' and not 'diameter'? The latter was simpler and of the same value, since the ratio $a^2 : b^2$ was the same as $\left(\frac{a}{2}\right)^2 : \left(\frac{b}{2}\right)^2$.

There was another little matter which was rather important. The word 'micro-photograph' was repeatedly used when 'photomicrograph' was meant. These two words were not synonymous. Micro-photographs were merely photographs of microscopic size. They were sold as souvenirs in such places as the Giant's Causeway and Niagara Falls. A photo-micrograph was a photograph of a small object enlarged by the microscope and might be of any convenient size. The difference was quite material, and certainly no petrologists should call a large photograph of a very small object by the name proper to a very small photograph of a large object.

Mr. H. F. Collins said there was one little point on which he would like some further information from the author, namely with reference to the micro-granitic dykes or stringers for which he suggested an origin similar to that of the sulphides themselves. If he understood the author rightly the suggestion was that just as the sulphides were squeezed out from certain sections of the magma because they were fusible, so the material forming the micropegmatite was squeezed out from other sections of the magma as being the more fusible portion.

He understood the author to argue that in districts where there were those micro-pegmatites, exploration or investigation work to look for sulphides was hardly indicated as probable, because the

micro-pegmatite was the most fusible material present in that particular zone and not the sulphides.

He would like to point out this. The author mentioned specially with regard to those dykes that their boundaries were sharp and well-defined where they cut the gabbros, and he could not understand how the micro-pegmatite could be a more fusible material than a gabbro. It could not possibly be. It was far more siliceous and therefore less fusible than the more basic material.

Rocks in general were more fusible the more basic they were. The analysis in Table I showed the micro-granite was distinctly a more siliceous material and therefore less fusible, not only than the gabbro but than the hornfels itself, and he could hardly conceive how the squeezed out origin supposed by the author could properly account for the occurrence of those micro-pegmatite stringers or dykes. They were no doubt proper dykes, but it did not seem sufficient to assume for their origin the fact that their constituent material could have been under any circumstances the most fusible part of the underlying magma. Possibly they were later intrusions from a separate and more deeply seated magma, but in any case they could hardly have been simply injected or squeezed out because of the greater fusibility of the material of which they were composed.

Mr. W. H. Trewartha-James congratulated the Institution and the author upon the presentation of such a very able paper.

He had risen for the purpose of expressing the hope that those who were not present that evening would not fail to contribute all they could to such a very important discussion; they were extremely grateful to those gentlemen who had spoken already, and who had given such an able insight into the critical points involved.

The suggestion that in all probability in the deeper strata there was considerable accentuation or concentration of the minerals was one of profound importance, and from his point of view it would perhaps add to the value of the paper if the author stated what methods could best be adopted to prove or disprove that theory, what would be the approximate cost of doing so, and perhaps he could forecast or express his opinion as to what probably might be expected to happen if such an enrichment had taken place, or, in other words, to give an approximate estimate of the tonnage and mineral value he expected to find.

From a very hasty glance at the paper it struck him that the mineralization of that mountain range had been very carefully studied, although it appeared to be so small as to be of doubtful commercial value at the present time. The author's interesting

enrichment at depth, made out a *prima facie* case for ther work; but one would want to know if the author into consideration what methods could be proposed for disproving that theory, and what it would cost to do so. object in rising was to congratulate the author on the on of such an able paper, and to express the most earnest those who could contribute to the discussion of such an subject would not fail to do so. He trusted they would y full discussion on the subject, in writing.

resident asked the author the distance of the Insizwa m the great Drachensburg Range, and the relation of the formation of the Insizwa Range to the other; also iere were any similar, though perhaps smaller, instances et formation in any other part of South Africa.

ed to him that the fact brought out by the paper and the as to the natural or geological concentration of the vas in itself sufficient to make the paper most valuable, which might well suggest further investigation on the

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LIST OF THE OFFICERS
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The Institution of Mining and Metallurgy
1916-1917.

The SECOND ORDINARY GENERAL MEETING of the Twenty-Sixth Session of the Institution of Mining and Metallurgy will be held, by kind permission, at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on THURSDAY, FEBRUARY 15TH, 1917, at **5.30** o'clock p.m.

The following Papers, copies of which are attached hereto, will be submitted for discussion:

The Wet Assay of Tin Concentrate.

By H. W. HUTCHIN, *Member.*

Hydraulic Tin Mining in Swaziland.

By J. JERVIS GARRARD, *Member.*

The Council invite written contributions to the discussion of Papers from any members who may be unable to be present at the Meetings of the Institution.

Tea, Coffee and Light Refreshments will be provided at 5.0 p.m., for members and visitors attending the Meeting.

NOTE.—The dates of succeeding Meetings will be announced in due course.

ADDRESSES LOST.

F. B. Bradshaw, P. R. Hudson, O. L. de Lissa, D. Nicholas, and J. F. Richards.

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the qualifications of Candidates for Admission into the Institution fulfil the requirements of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be open for inspection at the Office of the Institution for a period of at least two months from the date of the Bulletin in which their applications are announced.

The following have applied for admission since January 11th, 1917:—

To Membership—

Jones, John Evans (*Johannesburg, Transvaal*).

To Studentship—

Grut, Leslie de Jersey (*Melbourne, Victoria*).

The following have applied for Transfer:—

To Membership—

Stokoe, John Calvert (*Chin Mine, South Rhodesia*).

To Associateship—

Barrett, Victor Holmes McNaghten (*Randfontein, Transvaal*).
Leighton, Frederic William (*Wootton Bassett, Wiltshire*).

MOVEMENTS OF MEMBERS.

Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. F. W. Linck, M. Inst. M.M., has left England for Tavoy, Burma.

Mr. F. J. Martin, Assoc. Inst. M.M., is returning to England from the Straits Settlements.

Mr. E. F. Petersson, M. Inst. M.M., has left England for Spain.

Mr. G. Preumont, M. Inst. M.M., has left England for Bolivia.

Mr. Arthur J. Russell, M. Inst. M.M., has left England for the Republic of Colombia.

Mr. Sydney A. R. Skertchly, M. Inst. M.M., has returned to England from Peru.

INDEX OF RECENT BOOKS.

NOTE.—Books marked with an asterisk are contained in the Library of the Institution.

INDEX OF RECENT PAPERS.

NOTE.—All Papers indexed may be consulted in the Library of the Institution.

ASSAYING, ANALYSIS, CHEMISTRY.

Analysis of Molybdenum Ores. H. Westling and C. Andersen.—Mining and Scientific Press, San Francisco, Vol. 113, December 23, 1916, pp. 917-18. 10*c*.

Assaying Gold in Copper Matte. R. E. Chase, Junr.—Engineering and Mining Journal, New York, Vol. 102, December 30, 1916, p. 1139. 15*c*.

Electrolytic behaviour of Tungsten. W. E. Koerner.—Metallurgical and Chemical Engineering, New York, Vol. 16, January 1, 1917, pp. 40-7. 25*c*.

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Manufacture of Chromates from Chromite. H. French. Mining and Scientific Press, San Francisco, Vol. 113, December 9, 1916, pp. 845-6. 10*c*.

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Testing the strength of Explosives. J. A. Campbell.—Journal, Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, Vol. 17, October, 1916, pp. 66-9. 2*s*.

COAL.

Accounting System for Coal Mines. R. J. Maxwell.—Bull. No. 56, Canadian Mining Institute, Montreal, December, 1916, pp. 1101-28.

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Copper-Aluminium-Iron Alloys. (*Paper read before the American Institute of Metals.*) W. M. Corse and G. F. Comstock.—Metal Industry, London, Vol. 9, December 22, 1916, pp. 696-8; December 29, 1916, pp. 716-17. 4*d*.

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Sulphuric Acid from Copper Smelting Gases. E. L. Larison.—Engineering and Mining Journal, New York, Vol. 102, December 30, 1916, pp. 1121-5. *15c.*

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MILITARY SERVICE.

SUPPLEMENTARY LIST.

The following have been notified since the issue of the last Bulletin, January 11th, 1917:

MEMBERS SERVING WITH H.M. FORCES.

BEADNELL, H. J. L., Army Service Corps, (2nd Lieut.).

CHAFFEY, C. R., Manchester Regiment, (2nd Lieut.).

WACKRILL, C. H., South African Forces.

WILLIAMS, THOMAS, Royal Engineers.

PROMOTIONS OR OTHER CHANGES.

CHAPPELL, M. A., Royal Flying Corps, (2nd Lieut.).

CLUTTERBUCK, E. C., Royal Engineers, (2nd Lieut.).

CONRAN, R. H., Royal Engineers, (Captain).

DEAN, A. W. H. *Awarded Bar to Military Cross.*

DIXON, H. G. DACRES, Manchester Regiment, (Captain).

GRAHAM, W., attached Royal Garrison Artillery, (2nd Lieut.).

LINDSAY, The Hon. LIONEL. *Awarded the Military Cross.*

MANSFIELD, F. T., Hampshire Regiment, (Lieut.).

NICHOLLS, C., Royal Engineers, (Captain).

NISSEN, P. N., Royal Engineers, (Major). *Erroneously published in January Bulletin as* Sherwood Foresters.

PARGETER, C. E. *Awarded the Military Cross.*

WHITTUCK, J. C. S., Royal Engineers, (Captain).

KILLED IN ACTION.

WILLIAM NICKLIN, *Associate.* (No particulars.)

GERALD GALT, *Associate,* Lieut., Canadian Engineers. (*In France, December 25th, 1916.*)

CROWTHER & GOODMAN, LTD., Printers, 124, Fenchurch Street, London, E.C.

ect to revision.] [*A Paper to be discussed at a Meeting of the Institution of Mining and Metallurgy, to be held at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on Thursday, February 15th, 1917, at 5.30 o'clock p.m.*

The Wet Assay of Tin Concentrate.

By H. W. Hutchin, *Member.*

the literature available, the following publications may be ulted with advantage:

The Wet Assay of Tin Ores.'	J. J. Beringer, *Mining Magazine*, vol. i., p. 231.
Text Book of Assaying.'	C. and J. J. Beringer, 13th edition.
Technical Methods of Ore Analysis.'	A. H. Low.
The Assay of Tin and Antimony.'	L. Parry.
The Metallurgy of Tin.'	Thibault.
The Assay of Tin Ores and Concentrates.'	E. A. Wraight and P. L. Teed. *Trans.*, vol. xxiii.
The Assay of Tin Ores.'	H. W. Hutchin, *Trans.*, vol. xxiii.

n the discussion, 'On the Dressing of Tin Ores in Cornwall,' W. F. Wilkinson, 1913,* the late J. J. Beringer said:

I should describe the wet assay for tin as improved, rather n perfected. If the story of the introduction of wet assays into per mines is repeated with tin, then there will be a period of rovements in methods commensurate with the increased experie of methods and materials. I expect the improvement to come m discussion among professional assayers.'

The period predicted with such foresight appears to have ived, but even now it is only correct with the more advanced rkers. The conscientious worker seeks first to trace the weakss of his own methods, and having applied the remedy, he then tempts correlation with other methods. The author has attempted fulfil these conditions in compiling the data embodied in the

* *Trans.*, vol. xxii, pp. 215-228.

present communication, which in scope is restricted to the wet assay of tin concentrates, reserving for a future period a more critical study of the wet assay of low-grade ore and tailing. The task has been in part self-imposed, and in part compulsory; self-imposed as a continuation of the study of the lime method, and compulsory by the prevalence of divergent assays encountered in a professional capacity. The whole of the tests are new—i.e. actual experiments made since the last communication in 1914.

Recent metallurgical developments have made practicable the beneficiation of low-grade tin and tin-copper concentrates containing from 15 % of tin and 6 % of copper upward, and small quantities of low-grade tin concentrates are now being sold by Cornish producers.

Tin streamers and others find that it is to their advantage to sell a certain class of intermediate concentrate rather than dress it up to the grade usually required for black tin. This applies to what are known as 'hind' parts, that is, leavings from the cleaning up of black tin.

In other instances, where large proportions of hematite are associated with the cassiterite, it has been found more profitable to sell a low-grade concentrate than to dress this material up to a high-grade concentrate. So, too, in the magnetic separation of tin-wolfram concentrate from complex ores, the most magnetic product known locally as 'iron product' (18 %–21 % tin) is sold to best advantage without further treatment. At the same time it would hardly be profitable to sell as a low-grade concentrate a material containing crop tin, which could be easily dressed up to 60 % or 70 % grade. Nevertheless, the developments of this branch of metallurgy will be watched with interest, and perhaps with no keener interest than by owners of alluvial properties in Nigeria, where large quantities of low-grade concentrate are available, some of which is thrown away as worthless under present conditions. High freights forbid transport to England, but in due course with the development of the colony and facilities for metallurgical treatment at suitable centres, what are now worthless products may become of value. It is in the wet assay of such low-grade concentrates that difficulties have been encountered which, in the author's opinion, can now be successfully met: the difficulties are less frequently met with in the wet assay of high-grade concentrate; in low-grade concentrates extremes meet and experience gained with such material is invaluable in considering the assay of richer and cleaner material.

The iodine titration for the estimation of tin has met with wide

acceptance; ferric chloride with a less general acceptance. The former has the advantage of being more directly applicable.

For the assay of concentrates the standard solution of iodine should be of the strength of 100 cc. = 1 grm. tin. This will allow of a 1 grm. charge as a minimum being used for the determination. The standard solution should be made up in quantities of 15 to 20 litres at a time, standardized, adjusted to the required strength, and stored in Winchester quart bottles away from direct sunlight. The standardizing should be with pure tin: pure white arsenic, freshly dissolved, gives low results, involving an addition of roughly 1 % to the value. Thus if the standard by white arsenic was 0·99, it would be approximately correct to take it as 1·00. An alkaline solution of white arsenic several weeks old will give a value approximating more closely to that from direct standardizing with tin, indicating slow oxidation of the white arsenic in the alkaline solution.

Iodine solution, prepared in quantity and bottled in this manner, is fairly stable. Thus with a solution whose value at the time of bottling was 0·965, the last bottle of the stock, six months after, gave a value of 0·966. Loss of strength ensues during the period in which any particular bottle is in use. The remainders of two bottles which had been in use, containing each about 200 cc., were mixed together and standardized, giving a value of 0·962. A solution of potassium iodide in water usually acquires a yellow colour, due to liberation of iodine; on the other hand, with a solution of iodine in potassium iodide in daily use, the withdrawal of solution from stock bottle to burette gives increased surface and volume of air space for escape of iodine by vapour pressure, with a net result in time of diminished strength (serious difficulties with very dilute solutions of iodine arise from loss of strength). Where solutions of iodine are stored in aspirators, the solution should not come in contact with rubber; corks well waxed may be used. The entrance of deleterious gases of the laboratory must be guarded against by allowing the incoming air to pass through a trap containing iodine solution. The late Mr. J. J. Beringer — to whom the author is indebted for this procedure—gave it as his opinion that without the trap the iodine solution rapidly deteriorated; with the trap deterioration was much less. As an extra precaution, a log of standardizings was kept in a prominent position, which not only allowed the deterioration to be traced, but allowed any standardizing which appeared abnormal to be checked.

The pure tin should be rolled out very thin in clean bullion rolls: failing bullion rolls, very fine shavings, with a knife,

may be used. The quantity of tin used in standardizing should be about 0·7 grm.

Properly prepared, such a quantity will give no trouble in dissolving—gently boiling with 50 cc. hydrochloric acid for a few minutes is sufficient. After solution is complete, the volume should be increased to about 150 cc. with boiled water, and boiled with a nickel coil for five minutes.

Where a standard solution of tin is preferred (100 cc. = 1 grm.), about 70 cc. should be used. If freely acid, the excess of acid should be neutralized to leave only a few cc.'s excess, about 5 grm. of powdered zinc (free from tin) may be added to the cold solution and gently agitated: 55 cc. HCl are then added cautiously, the nickel coil inserted, boiled and boiling continued for 10 minutes. The nickel should be in the form of a coil and suspended by a glass rod; on removal (and it is better to remove it) it should be washed with boiling water. The reduced tin solution should be cooled under CO_2 in the manner described in Beringer's 'Text Book.' Solution of the tin in a concentrate may not be effected without a preliminary operation, which may be accomplished in various ways, e.g.:

(1) By heating the finely powdered charge in a current of hydrogen, coal-gas or other reducing gas. The reaction is the basis of the old and well-known method of assay and commonly known as the 'hydrogen' method. Heating the concentrate with carbon for some hours is applied also.

(2) Ignition of the finely powdered charge with metallic zinc in the presence of a basic oxide, preferably zinc oxide.—Beringer method.

(3) Ignition of the powdered charge with lime in the presence of the products of combustion of a bunsen burner or blow lamp.—Hutchin or lime method.

(4) Fusion of the powdered charge with caustic soda or sodium peroxide.—Pearce method.

The 'hydrogen' method (except for an old method involving a gravimetric determination) appears to have been used only in conjunction with the ferric chloride titration, so, too, with the carbon reduction. The Pearce, lime and Beringer methods have all been used in conjunction with the iodine titration and may not be used for the ferric chloride titration so long as a reduction with nickel is used. But with a separation with zinc and care in redissolving the precipitated tin the ferric chloride titration could be used.

Before any of these reactions can be utilized in an assay, the sample of concentrate must be in a suitable state of subdivision.

This is accomplished by mechanical means. Rough alluvials and jig samples require a preliminary reduction in size, usually by muller and slab, ball-mill, or other mechanical appliance, before finer grinding is attempted. With concentrates of limited size, such as are produced in ordinary milling operations, the preliminary reduction may be dispensed with or modified somewhat, but, generally speaking, some degree of fine grinding will be necessary.

It is in operations of this kind that very serious error may be introduced: the worker obtains in duplicate assays a delightful concordance without a suspicion that errors of 1 %, 2 % or 3 % may have been introduced before even the charges had been weighed out. This is not so with all workers, but the error is more common than is desirable, and, what is of more importance, by no procedure within the author's experience can any but low assays be returned on certain rough samples—viz., alluvial tin concentrate, jig samples of tin and tin-wolfram concentrate. F. A. Eastaugh has referred to similar difficulties in the estimation of ash in coke.*

The Beringer assay requires an impalpable powder; the Pearce assay allows of greater latitude in size; the lime assay allows the widest latitude, and for this reason its use has been continued by the author. The days of laborious fine grinding are no more, and the evils also; with many products mixing rather than grinding is required, but a large charge is taken as a precaution against possible sampling errors. Possible fine grinders are the agate, steel and Wedgwood mortars, muller and slab, disc grinders, and ball-mills. The case against ball-mills and disc grinders rests on the experience of other workers, but with the other appliances careful investigations have been made. That makers of disc grinders supply duplicate discs is significant: with ball-mills as used at the Camborne School of Mines the weighing of the balls supplied convincing evidence of dilution of the sample. Further, of disc grinders, Ernest A. Smith has stated: 'It may be well in this connexion to point out that, when the fine crushing of poor ores with hard gangue is effected in disc grinders, there is considerable danger of the sample becoming contaminated with from 2 % to 3 % of iron, or even more.' †

Fine Grinding—Experimental. About 600 grm. of a Cornish black tin ('Crop tin') was digested on a water bath with hydrochloric acid for some hours and a little nitric acid added towards the end. The cleaned concentrate was washed with water till free

* 'The effect of different methods of crushing on the Ash of Coke.' *Trans.*, vol. xxiv., p. 483.

† *Trans.*, vol. xxiii., p. 335.

from acidity, then treated with dilute ammonia to remove traces of tungstic acid, again washed thoroughly with water and dried.

A 10 grm. charge of the cleaned concentrate gave no blue colour in a volume of 50 cc. by the ordinary colorimetric assay for copper, and may be considered free from copper. With this material a set of six assays was made. In each instance 5 grm. charges were heated with 6 grm. of lime; the residues obtained were reground in agate mortar, mixed with a little lime reheated, and the small quantity of tin dissolved in acid and added to the main tin solution. This gave 6 solutions of 500 cc. each, 100 cc. of each solution were reduced with nickel.

The first assay was with unpowdered material, the second with the material powdered in an agate mortar, the third with the material powdered in a steel mortar, and the remaining three assays with material powdered in various Wedgwood mortars which may be designated A, B and C respectively.

For the steel mortar and pestle the author is indebted to the Camborne School of Mines: it was designed by and cast for the late Mr. J. J. Beringer, from a supply of Hadfield's hard steel.

The Wedgwood mortar A was of the variety glazed outside, unglazed inside; B and C were both of the ordinary unglazed type.

The percentages of tin returned in the six assays were—unpowdered 75·1 %, agate powdered 75·1 %, steel powdered 74·0, Wedgwood powdered, A 73·35, B 73·65, C 72·95. Within the limits of experimental error grinding in an agate mortar does not result in dilution of the sample.

The colour of the powdered material from the steel mortar was much darker than that from the agate. An attempt to estimate the iron in the former by contact with excess of a copper solution and a colorimetric estimation of the precipitated copper indicated only 0·5 % metallic iron, but an alternative method based on solution in *dil HCl, peroxidizing and precipitating as ferric hydrate gave 1·6% calculated as iron—a blank test on the agate powdered material was also made, the amount from the blank was very little.

So, too, the evidence against the Wedgwood mortars does not rest solely on the three assays quoted: the following series of assays on ten different samples of concentrate, Cornish and foreign, should bring conviction. They are taken from preliminary investigations on the application of the lime method to unpowdered concentrate.

* The smell of carburetted hydrogen was quite noticeable.

COMPARATIVE ASSAYS.—POWDERED AND UNPOWDERED.

The powdering, except where stated, was by Wedgwood mortar.

No. of Sample.	Lime Method, unpowdered.	Lime Method, powdered.	Beringer Method, powdered.
	%	%	%
I.	73·4	71·3	70·9
II.	69·0	67·6	67·2
III.	77·3	75·45	75·0
IV.	70.95	—	69·0
V.	68·25	—	66·1
VI.	70·7	—	67·8
VII.	67·25	—	64·8
VIII.	72·0	—	69·7 (agate 71·9)
IX.	70·7	—	68·0
X.	75·6	72·65	72·75

The differences are clearly due to the method of grinding and not to differences in methods of assay.

The log of the weights of the Wedgwood pestles B and C are also convincing. The mortar and pestle B, originally new in 1907, was used for general purposes, but more particularly for fine grinding tailing samples. By 1912, not only had the pestle worn away to the wooden handle and was replaced by a new one, the base of the mortar had taken a distinctly new shape by erosion.

The log of the weight of the new pestle B runs:—March 13, 1912, 275 grm.; June 13, 1912, 264 grm.; February 25, 1914, 237 grm.; May 19, 1914, 236 grm.; March 20, 1915, 235 grm.; August 12, 1915, 234 grm. From March 13, 1912, to June 13, 1912, it was used indiscriminately for concentrate both tin and wolfram, the approximate number of samples prepared in this period was 240. The conditions were the same from June 13, 1912, to February 25, 1914, but the number of samples treated is not clear. From

February 25, 1914, only wolfram concentrates were prepared with the mortar, and in the period from February 25 to May 19 the number of wolfram samples prepared was approximately 50. From May 19, 1914, onwards it was in use for wolfram only.

With regard to pestle C, its weight on February 26, 1914, was 445 grm., and by May 19, 1914, its weight had decreased to 437 grm.; in this period it was used only for tin concentrate, and the approximate number of samples was 30.

Thus the records show that in the preparation of 50 samples of wolfram the pestle lost 1 grm. in weight, as against a loss in weight of 8 grm. in the preparation of 30 samples of tin concentrate.

The bucking board or muller and slab so commonly used in laboratories were also investigated. The material used for the purpose was a stock of Nigerian concentrate from the Bauchi district. It was fairly uniform in size, too large for direct use by any method, but not so large as gravel. The proportion passing a 60-mesh sieve was small, +20, +40, +60 indicate the range of size in about equal proportions.

50 grm. was carefully reduced to a suitable size by means of the agate mortar and, after careful mixing, a 5 grm. charge was taken, giving 500 cc. of solution for assay. By a colorimetric assay the TiO_2 per 100 cc. of the assay liquor was 8 milligrams. On an aliquot part 100 cc. reduced with nickel the percentage of tin was 70·82, but on another aliquot part precipitated with zinc and separated from the titanium the percentage was 70·72 %. Details of the separation from titanium with zinc are given later.

The muller and slab were cleaned with several lots of concentrate, 200 grm. of the concentrate was then brought down with the minimum of rubbing to a size a little rougher than a Cornish crop tin—a quantity was withdrawn for assay purposes, sample I, and the remainder brought down a little finer, but with care to avoid undue rubbing, sample II.

The slab was again cleaned with rubbings of concentrate and a further quantity was ground in two stages as before, giving sample IA and sample IIA respectively.

The slab was again cleaned with more concentrate, and the operation of reducing the sample a third time, giving sample IB and sample IIB.

Samples IA and IB were not assayed for tin: the other samples were, and 5 grm. charges were used as in the case of the agate powdered material. The percentages of tin returned were: sample I, 69·6; sample II, 69·0; sample IIA, 70·0; and sample IIB, 70·1.

The assays of samples I and II indicate that the slab was not sufficiently clean, the concordance with samples II$_A$ and II$_B$ that a clean slab had been secured. Used with the utmost care the muller and slab are decidedly objectionable, and in the hands of a lusty laboratory attendant they would be still more so.

It is clear that there are distinct limitations in the methods of preparation of samples and although these limitations are most with rich material they persist proportionally with less rich material. In the preparation of rich material, such as a sample of Cornish black tin, the dry material should be well mixed in a Wedgwood mortar, but there must be no grinding. The thoroughly mixed sample is transferred to a sheet of paper, levelled off with a spatula, and a number of parallel cuts taken with the spatula and transferred to a 4-in. agate mortar, where it is reduced to the required fineness.

With intermediate concentrates, which are usually rougher and more diverse in composition than black tin, a modified treatment may be given. The dry material is thoroughly mixed, spread on paper and a quantity cut out as before, and reduced a little in size on a Wedgwood mortar; but care must be exercised not to powder too freely—the aim of the worker should be to reduce the proportion of oversize material. This reduced material is then cut out and finished in an agate mortar. With rougher material, such as shipments of alluvial concentrate, most commonly the preparation of the sample is performed by professional samplers, and the prepared samples forwarded to the assayers for the buyers and sellers. The common method of crushing with steel rolls calls for investigation; meanwhile, samples so crushed are open to suspicion. As a substitute the old-fashioned bell metal mortar should answer the purpose; it should be investigated with a copper free material. It should be used solely as a breaker, not as a grinder.

Both in the hydrogen and carbon method, the cassiterite is reduced to metallic tin—in the Beringer method also to metal: but as it is more or less alloyed with zinc, it is best regarded as a tin-zinc alloy. In the Pearce method, sodium stannate is produced, and in the lime method a basic stannate of lime. Where the method gives a metallic product, solution is effected in strong hydrochloric acid; but when the stannates result solution is effected in dilute acid, the most easily soluble is the sodium stannate. Where the method yields a metallic product, its solution in acid is mainly stannous, and after dilution to the required volume a short reduction (5-10 minutes) is all that is necessary, and is obviously the direct method. As an indirect method, the solution of the tin

may be peroxidized with permanganate of potash (chlorine attack), and reduced for a longer period (20-25 minutes). In the Pearce and lime methods the opposite obtains, since the solution in hydrochloric acid is wholly stannic, and the longer period of reduction with nickel is required; but the worker has the option in each instance of a less direct method, viz., by a preliminary treatment of the stannic solution with metallic zinc. The details of procedure have been given in the method of standardizing with a standard solution of tin. Solution of the melt in a Pearce assay may be made with a minimum excess of free acid; the lime method, too, presents no difficulty in securing a solution with but little free acid, but not quite so little as in the Pearce method.

The reduction of a tin solution may be accomplished in two ways: (1) wholly with nickel--nickel reduction; (2) a partial reduction with zinc and completed by nickel—'zinc-nickel' reduction. Either procedure may be followed with any of these methods.

For zinc-nickel reduction about one minute's contact with the stannic solution is sufficient, but the precipitation of the tin is incomplete. By prolonging the time of contact complete precipitation is secured, and used in this way furnishes an alternative method for the removal of undesirable impurities such as titanium, tungsten, cerium, molybdenum, etc. The time for complete precipitation is proportional to the amount of free acid. With 100 cc. of assay liquor (representing 1 grm. of black tin) from a lime assay and containing about 9 cc. free hydrochloric acid a period of 40 minutes was required, but in a Pearce assay with a 1 grm. charge in a bulk of 100 cc. and only 2 or 3 cc. free hydrochloric acid a period of 15 minutes was sufficient.

The substitution of nickel for iron as a reducing agent was an improvement and has met with general acceptance; in the author's opinion zinc-nickel reduction is a further improvement. Ferrum redactum and aluminium are alternatives to zinc as partial reducers but neither admit of a separation. Ferrum redactum used in conjunction with the fusion methods has failed badly with low-grade Cornish concentrates. In the presence of arsenic the assays were very low, and when the material was given a preliminary calcination to remove arsenic the assays were frequently high. With acid cleaned concentrates it is quite conceivable that better results would be obtained.

The worker who uses a large charge, and reduces aliquot parts of the solution of the charge, has the opportunity of testing the efficiency of reduction with nickel by the degree of concordance in

duplicate titrations. Such a practice ensures that discrepancies are located solely to failure of the nickel. It is true that such failures are not common, but they do occur oftener than is desirable—hence the preference for zinc-nickel reduction. Examples from the record book of such failures are: 17·75 and 18·55, 19·8 and 19·3, 18·1 and 17·1.

The efficiency of the nickel may be tested as recommended by Beringer; but this does not ensure that its efficiency is not impaired by the assay liquor into which it is subsequently introduced. Do not tolerate inefficient nickels, but limit the demand to as little as possible—a condition which is obtained when a preliminary reduction is made with zinc.

But all these precautions, care in grinding, complete solution of the cassiterite and care in reduction to stannous may be of no avail in the presence of interfering substances. The worker who 'acid cleans' knows nothing of interferences. The term acid cleaning is used in its broadest sense and includes: (1) a short boiling with hydrochloric acid, and finally a little nitric; (2) a prolonged boiling with hydrochloric acid, as in the method for the assay of wolfram concentrate, with the removal of tungstic acid by means of ammonia or dilute soda; (3) fusion with bisulphate of potash. When to use any of these methods is determined by experience and a knowledge of the source of the material.

With an unknown material the liquid from the acid cleaning must be tested for tin by the usual sulphuretted hydrogen separation. There is an alternative method which is simpler and more expedient. The boiling liquors are precipitated with ammonia, filtered and the precipitate well washed. The washed precipitate is redissolved in a sufficient excess of hydrochloric acid, diluted to about 150 cc. and reduced with a nickel coil.

The product from the bisulphate fusion is best leached out with the addition of hydrochloric acid and water and filtered. The filtrate requires testing for tin.

Interference may result from different causes—e.g. (1) a deposition of sediment on the nickel whereby its efficiency is impaired and the complete reduction to stannous is not secured; (2) the sediment deposited may contain tin; (3) the sediment if in suspension in a finely divided state may consume iodine; (4) the impurity remaining in solution may consume iodine directly or indirectly by an induced reaction. Tungstic acid is an example of induced reaction. There are other induced reactions of which it cannot be said that any particular impurity is the cause, which are a summation of conditions inducing consumption of iodine. With

some concentrates the assays are lower when acid cleaned than when not cleaned; solubility of the tin contents is no explanation, for in the examples in the author's mind no tin was found in the acid liquors; nor were the impurities present in sufficient quantity to supply a reasonable explanation.

With other kinds of material acid cleaning is a precaution against variable assays. In the absence of acid cleaning the results may be erratic and the assayer invites trouble who persists in taking the easy way of omitting to clean with any and every kind of tin concentrate without any knowledge of its composition.

The effect of impurities may be studied by synthetic methods or by analytical methods. By synthetic methods solutions of the impurities may be added to a solution of tin of known strength, or minerals of known composition may be added to tin concentrate of known quantity. By analytical methods the assay is made with the impurities present and compared with the assay with the impurities removed. Both methods must be considered in arriving at conclusions.

SYNTHETIC STUDIES OF THE EFFECT OF IMPURITIES.

A stock solution of a clean tin ore was used such that 100 cc. = 1 grm. black tin and contained about 9 cc. HCl per 100 cc.

	Vol. of tin solution used.	HCl added.	Impurity added in milligrams.	Nature of Reduction.	Period of Reduction	Iodine required.
	cc.	cc.			min.	
1	100	30	—	Nickel	20	71·4
2	100	45	—	,,	20	71·6
3	100	45	—	Zinc nickel	10	71·6
4	100	45	25 As_2O_3	Nickel	20	71·5
5	100	45	50 ,,	,,	20	71·0
6	100	45	25 WO_3	,,	20	71·85
7	30	45	65 ,,	,,	20	21·7
8	30	45	125 ,,	,,	20	21·75
9	80	45	125 ,,	,,	20	57·8
10	20	55	—	Zinc nickel	10	14·35
11	20	70	180 Copper, 400 Iron	Nickel	20	7·25
12	20	70	,,	,,	20	6·5
13	20	90	,,	,,	20	11·4
14	25	50	100 Copper, 50 As_2O_3	,,	20	15·0
15	100	45	25 Cu, 25 As_2O_3, 30 WO_3	,,	20	71·4
16	100	45	70 $AmMoO_4$	,,	20	72·2

Tungstic Acid.—The interference of tungstic acid is confirmed. Of the various methods of assay the conditions of the experiments

would be most nearly realized in the Pearce assay. With the alkaline fusion wolfram and scheelite are converted into easily soluble tungstates, but it is quite possible that with arsenic, silica, etc., present in the sample more complex acids, and less readily decomposed with acid to yield precipitated tungstic acid, such as arseno-tungstates, silico-tungstates, etc., would be produced. There is no evidence, however, to prove that a very soluble tungstic acid gives a greater interference than the colloidal. For exact determinations it is obvious that tungstic acid should be removed. In the Beringer assay the conditions are modified by the fact that wolfram is reduced to a metallic product with only a slight solubility in acid. In the lime method the attack is not so vigorous as with the caustic alkalies, and a digestion with dilute HCl will dissolve out the stannate and leave the tungstic acid in a form suitable for removal by filtration. In the Pearce assay it is not always possible to remove the tungstic acid by filtration: when complex tungstates are formed the solubility in hydrochloric acid is very pronounced.

Arsenic.—With this impurity it is difficult to avoid low results. There are two possible explanations. The deposit on the nickel may impair its efficiency and the complete reduction to stannous is not attained; on the other hand the black deposit may carry tin and in the author's opinion probably does, but no direct determinations appear to have been made. The author's general experience with assays on rank arsenical material without acid cleaning has not been very encouraging, and some of those experiences cannot be satisfactorily explained other than by a loss of tin in the precipitated sediment. In high-grade concentrate the smelter discourages other than small amounts of arsenic, 0·25 % or less; in intermediate concentrate, especially if not calcined, *large proportions of arsenic may be present and are better removed.*

Copper.—No apology is needed for titrations 10, 11, 12, 13 and 14 after Beringer's remarks with respect to copper. On page 302, *Trans.*, vol. xxii, he says:—'And copper ores should be treated with acid before assaying for tin, for reasons discussed later in some comments on the behaviour of stannine.' The comments on page 304 are—'Low results may easily be obtained by the method of nickel reduction followed by titration with iodine, if unreasonably dirty liquors are worked upon.' Thus ½ grm. charges of stannine (containing 26 % tin) will give hopelessly low and irregular results if they are merely dissolved in the flask, reduced with nickel and titrated. The difficulty will almost certainly be removed by a little systematic investigation, and there is no difficulty in getting good results from stannine by boiling up with nitric acid and running

the assays as an acid cleaned concentrate. There are other grounds for acid cleaning, and its lack of effect must be determined on unknown material before it is omitted. There are cases in which the effect of fusion with an alkaline bisulphate should be tried: in these cases tin must be recovered from the liquor, for some tin from cassiterite is made soluble in the fusion.

The erratic behaviour of copper in the synthetic studies is met in the assay of concentrate containing more than small percentages. Three samples, A, B and C, are taken from the same mine. A and B are intermediate concentrates, not calcined, and would contain from 13 to 14 % sulphur, 10 to 11 % copper, and some arsenic. C is a concentrate produced from the 'burnt leavings' of the mine and contained fully 15 % copper.

The assays of A and B were by the lime method; A returned 22·75 % tin when acid cleaned, and 18·7 % Sn without cleaning, similarly B returned 23·05 % and 17·85 % tin respectively for similar conditions.

Concentrate C gave 15 % acid cleaned, 15·35 % without cleaning: the referee on the reference sample returned 15·0 %. These assays were supplemented by a Pearce assay with 2·5 grm. of uncleaned material. The solution of the melt was made up to 250 cc. 100 cc. of the stock solution reduced with nickel gave 15·5 %, a second portion of 100 cc. reduced with zinc-nickel gave 15·05 %. In the zinc-nickel reduction the copper precipitated along with the tin by the zinc refused wholly to dissolve subsequently in the stronger acid, and there are good reasons to believe that it retained tin.

When small charges are used the amount of copper (and of other impurities) in the solution is reduced in quantity and less likely to give disturbance. Wraight and Teed, workers with small charges, evidently encountered difficulties not recorded in their published assays, for they say with respect to copper:—'It is impossible to state at what percentage it is necessary to adopt special precautions; but when copper is associated with tin, the assayer should remove it by giving the ore a preliminary treatment with nitric acid. By comparing this result with that obtained when no nitric acid cleaning has been used, he will be able to decide whether such treatment must always be adopted on this class of ore.'

There are no difficulties in the way of the removal of copper, arsenic, and tungsten; the author's preference is for acid cleaning rather than by alkali for the latter.

Titanium.—With respect to the interference of titanium the position improves with experience. It has been accepted that the period of reduction with nickel is an important factor, a short

reduction gives less interference than a long one. The last word has yet to be said. Much valuable information may be obtained by adopting the practice of working with large charges and reducing an aliquot part by nickel or zinc-nickel, and comparing this with the value of another aliquot part after a separation of the tin from titanium with zinc. Some workers state that titanium does not interfere, others that it does, and amongst the latter there is a difference of opinion as to the degree of interference. There must be a reasonable explanation for such diversity of experience. The author's experience has been such as to enable him to sympathize with both theories. The principal factors appear to be: (1) the brand and purity of the nickel used; (2) the period of reduction; (3) the manner of making the actual titration; (4) the concentration and acidity of the assay liquor.

At one period thin sheet nickel was purchased from Messrs. Baird & Tatlock, London. Cut into lengths 9 in. × 1¼ in. the material was easily rolled into coils, and for many years no other was used. At a later date ready-made coils of thicker material and larger area were purchased from the Metallic Compositions Co., London, and at a still later date ready-made coils from the Metal Coverings Co., London. Reviewing the whole of the author's experience of titanium, the Baird & Tatlock nickel is characterized by little or no interference, the other brands were associated with all the instances of high interference, but it was not characteristic of the whole of any particular batch of coils; the problem seemed very elusive.

Two distinct cases of titaniferous material, one a poor and the other a rich material, came under examination during the period when Baird & Tatlock nickel only was in use and before the titanium question became acute. The poor material was assayed by the Beringer method, with the titanium present, and with it removed by the bisulphate fusion. The liquors from the bisulphate fusion were free from tin and both assays were in very close agreement.

The rich material (agate powdered) was assayed by the Beringer method, but the tin solution from the zinc-tin alloy was first peroxidized with permanganate and then reduced with nickel. The assay was returned at 60·5 %—two other assayers had reported 64 to 65 %—with the prominence given to titanium recently this material was re-examined. The results were with titanium present 60·66, 60·6 and 60·63, on charges of 5, 2·5 and 1 grm. respectively; with titanium removed by evaporation with hydrochloric and hydrofluoric acid 60·5 %, of which 0·2 % was in the fluoride solution.

At the *period when Messrs.* Wraight and Teed's paper was

published, both Baird & Tatlock nickel and the Metallic Compositions Company nickel were in use; this added to the general confusion. The net result was that, as a precautionary measure, the author retained an open mind with respect to titanium interference, and commenced fresh investigations. In a preliminary series of titrations (Series A), the effect of time and brand of nickel was dealt with. The titanium added was as a solution of rutile, and in some instances ilmenite, dissolved in fused bisulphate, etc. The tin solutions were surplus assay liquors; titrations, 4 to 10 inclusive, were with the same solution; 11, 12 and 13 on another. Titrations, 4 to 13, should only be taken as comparative as the value of the two solutions without titanium was taken from earlier determinations.

TITANIUM.—SERIES A.

	Time of Reduction.	Brand of Nickel.	TiO_2 added in milligrm.	Iodine required.	Iodine required without TiO_2.
1	45	M. Comp. Co. Old Stock	50	72·4	71·2
2	20	,, ,, ,,	50	68·35	67·55
3	20	,, ,, ,,	50	76 6	75·2
4	20	,, ,, ,,	100	32·9	32·55
5	20	,, ,, New Stock	100	32·7	32·55
6	20	Baird & Tatlock	100	32·55	32·55
7	40	,, ,,	100	32·75	32·55
8	20	,, ,,	50	32·55	32·55
9	20	,, ,,	50	26·0	26·0
10	20	,, ,,	50	16·25	16·25
11	40	M. Comp. Co. New Stock	100	32·40	31·9
12	20	,, ,, ,,	75	64·60	63·85
13	20	Baird & Tatlock	75	64·20	63·85

Under zinc-nickel conditions of reduction a duplicate of No. 1 gave 71·5 cc. (M. Comp. Co. nickel), a duplicate of No. 10 gave 16·3 cc. (Baird & Tatlock nickel); in a third titration, with TiO_2 absent 57·45 cc., but with 75 mg. TiO_2 added 58·3 cc. (Baird & Tatlock nickel).

In these three experiments zinc strip was used, and as a result in the third experiment, with the large amount of tin, a prolonged boiling of the sponge of tin with the acid liquors was necessary to redissolve it. It would appear that a prolonged digestion with metallic tin is as objectionable as with nickel. Zinc powder is more suitable than strip. The working notes of the period with respect to the manner of using zinc powder are:—100 cc. of tin liquor (containing about 9 cc. HCl) were measured carefully into an 8-oz. pear-shaped flask, 4 grm. zinc powder added and warmed.

45 cc. HCl were added cautiously and brought to the boil, the nickel coil inserted and boiling continued for 5 minutes after the metallic precipitate had redissolved. A test of this procedure with 100 cc. of tin solution with 50 mg. TiO_2 added and 100 cc. without TiO_2 was successful, 62·5 cc. iodine being used in each.

This procedure was followed subsequently, except that after the addition of zinc powder raising of the temperature was deferred till after the addition of the 45 cc. HCl.

With the experience gained in Series A, two other Series B and C were made. In Series B the tin solution was such that 100 cc. represented 1 grm. of tin ore, and the iodine solution of strength to correspond 100 cc. = 1 grm. of tin. In Series B the tin and iodine solutions were half as strong. For practical purposes the cc. of iodine used in each series may be taken as percentage of tin.

The titanium added was as a solution of rutile. The initial bulk before production was in all cases 170 cc. The value of the tin solution was determined in duplicate, one reduced with nickel, the other with zinc-nickel, the amount of free HCl in all cases would be represented by 50 cc. HCl. The period of reduction with nickel was 20 minutes from the time of bleaching. The tin solutions were free from TiO_2 by a colorimetric test.

TITANIUM.—SERIES B.

	Vol. of Tin Solution used.	TiO_2 added in milligrams.	Brand of Nickel used.	Nature of Reduction.	Iodine used in cc.
1	100 cc.	nil	Baird & Tatlock	Nickel	67·9
2	,,	nil	,,	Zinc-nickel	67·9
3	,,	1·25	,,	Nickel	68·0
4	,,	2·5	,,	,,	68·1
5	,,	5·0	,,	,,	68·1
6	,,	5·0	,,	Zinc-nickel	67·9
7	,,	10·0	,,	Nickel	68·1
8	,,	10·0	,,	Zinc-nickel	67·85
9	,,	15·0	,,	Nickel	68·3
10	,,	25	,,	,,	68·2
11	,,	25	,,	Zinc-nickel	67·95
12	,,	50	,,	Nickel	68·1
13	,,	50	,,	Zinc-nickel	68·0
14	,,	20	,,	Nickel—2 coils	68·2
15	,,	20+150Fe	,,	Nickel	68·2
16	,,	25	M. Comp. Co. (new)	,,	68·15
17	,,	20	,, (old)	,,	68·3

Titanium.—Series C.

	Vol. of Tin Solution used.	TiO_2 added in milligrams.	Brand of Nickel used.	Nature of Reduction.	Iod
1	100 cc.	nil	Baird & Tatlock	Zinc-nickel	
2	,,	nil	,,	Nickel	
3	,,	5	,,	,,	
4	,,	10	,,	,,	
5	,,	15	,,	,,	
6	,,	20	,,	,,	
7	,,	50	,,	,,	
8	,,	50	,,	Zinc-nickel	
9	,,	50	,,	Nickel and 2 coils	
10	,,	50	M. Comp. Co.	—	

The position, with smaller quantities of tin and inc
titanium, is given in Series D. The tin solution and iodine
tion were both of strength, roughly, 100 cc. = 1 grm.

Titanium.—Series D.

	Vol. of Tin Solution used.	TiO_2 added in milligrams.	HCl added in cc.	Initial Bulk.	Io
1	25	nil	45	170	
2	25	200	45	170	
3	25	50	45	170	
4	25	200	70	170	

Nickel only was used for the reduction in all four instan
experiment 4 bleaching of the blue coloration was pron
and too great an acidity appears to have a bad effect.

The experiments with 100 cc. of tin solution give a low
of interference in which zinc-nickel reduction comes ou
creditably. Area of nickel as shown where two coils wer
instead of one does not appear to count. With the pa
samples of coils used there is no marked difference betw
two brands of nickel, and the matter would have been con
disposed of except for the receipt of coils from another sour
The Metal Coverings Co. It is characteristic of some of th
from this source that a fine black scum is liberated from the
during reduction even in very clean liquors—this character
retained during its life. Such a coil was selected for a te
titanium.

100 cc. of a tin solution without titanium reduced by zinc

(Baird & Tatlock) required 71·6 cc. iodine, the same quantity of tin solution with 50 mg. of TiO_2 added and a 20 minute reduction with the Metal Coverings coil required 72·3 cc.

In all these titrations the author's practice was to run in the iodine to within a cc. or so of the required quantity without agitation, then agitate gently and finish the titration little by little but speedily. As a variation the alternative method was tested, viz., the iodine run in briskly with gentle agitation at the same time. For this purpose the same batch of the Metal Coverings Co. coils was used.

With 100 cc. of tin solution, 50 mg. TiO_2, 45 cc. HCl and initial bulk of 175 cc., and a 20 minute reduction 71·7 cc. iodine were required as against 71·6 without titanium.

There still remained the question as to what effect would be produced in the titration when the nickel coil was allowed to remain. The previous experiment was repeated except that a Baird and Tatlock coil was used and left in the reduced liquor—71·85 cc. iodine were required; with half the quantity of tin solution and 80 cc. HCl, 36·0 cc. iodine were required. In the first of these experiments with the nickel left in the liquors there was rapid bleaching of the blue coloration, but no bleaching in 10 minutes after removal of the nickel. The presence of titanium rather stimulates the rate of reduction with nickel than retards it.

In all these synthetic experiments solutions of tin ores and solutions of titanium minerals were used. The synthetic method was next extended to the study of the effect produced by adding the minerals rutile and ilmenite respectively to tin concentrate of a high degree of purity. A preliminary assay indicated about 77 %, and it was assumed that any small amount of titanium in it would be rutile, as is most frequently the case with cassiterite from Cornish lodes. With the particular method of assay adopted rutile does not pass into solution.

The rutile used for addition was powdered crystal of good purity; the ilmenite contained approximately 40 % TiO_2.

Three charges, each of 5 grm., and one of 1 grm. were carefully weighed out. To one nothing was added, to the second 250 mg. of powdered rutile, to the third 500 mg. of powdered ilmenite, and to the fourth—the 1 grm. charge—4 grm. of powdered ilmenite. Each charge was mixed with 6 grm. of clean lime and heated in the Bunsen furnace for 20 minutes. The cold charges after firing were dissolved in 60 cc. HCl, diluted with 15 cc. of water and well boiled. The extracts after dilution were filtered through ashless papers into 500 cc. graduated flasks, washed, etc., and the

solution diluted to 500 cc. The weight of each residue was determined, mixed with more lime, refired, etc., and the small quantity of tin in each estimated separately, calculated to SnO_2, from which the weight of real residue could be calculated.

With the four stock solutions of tin, 500 cc. each, titrations were made in duplicate—one with nickel, the other with zinc-nickel reduction. A determination of the TiO_2, in each solution, was made by the usual colorimetric method.

TABULATED DATA OF THE FOUR ASSAYS.

No. of Assay.	Weight of residue, less SnO_2.	Tin as per cent. in residue.	TiO_2 per 100 cc. of assay liquor.	Iodine in cc. per 100 cc. of assay liquor and nickel reduction.	Iodine in cc. per 100 cc. assay liquor zinc-nickel reduction.
I.	·0607 grm.	·26	nil	77·65	*77·65
†II.	·3120 „	·15	nil	77·7	77·8
III.	·3835 „	·06	5 mg.	77·85	77·85
IV.	2·774 „	·11	25 „	†15·65	15·65

* Another 100 cc. with 15 mg. TiO_2 added in solution required 77·85 cc.

† Three estimations in all were made—two with Metallic Composition Co.'s nickel, each required 15·65; the other with Baird & Tatlock nickel required 15·55 cc. Otherwise coils from the Metallic Compositions Co. were used throughout the series of assays.

The standardizing of the iodine solution with metallic tin gave 100 cc. = 0·99 grm. Sn, with pure white arsenic gave 100 cc. = 0·979 grm. Sn.

The assays worked out at 77·16, 77·12, 77·13, and 15·59 % (should be 15·43 % as calculated on Assay I).

The weight of rutile recovered in Assay II was 251 mg., and the weight of ilmenite recovered in Assay III was 328 mg., and as only 25 mg. of TiO_2 actually went into the whole of the 500 cc. of assay liquor, it is evident that splitting off of iron oxide from the ilmenite had taken place. The weight of ilmenite recovered in Assay IV was 2·762 grm., and the total TiO_2 in solution in the assay liquors was 125 mg.; here again splitting off of iron oxide from the ilmenite is pronounced. This shows that in the lime assay rutile may be disregarded, also that with ilmenite there is a limited degree of attack, but apart

from this, the figures are of general interest inasmuch as the amount of TiO_2 in the assay liquors is definitely reported.

There still remains the consideration of titanium from the analytical point of view. Two examples will suffice, one a high-grade concentrate, the other a typical low-grade Nigerian concentrate. The high-grade concentrate has been referred to in the muller and slab experiments, giving an assay of 70·82 %, with titanium present, and 70·73 % with the titanium removed by separation with zinc.

The low-grade concentrate was brought down with the muller and slab to a convenient size in order to minimize possible sampling errors. The absolute value of the sample is therefore speculative but for the purpose the comparative assays are sufficient. Two assays were put in hand with 5 grm. charges and 6 grm. of lime, the tin in the residues from the main assay was determined separately. The first assay was with the titanium minerals present, the second with the titanium removed by a bisulphate fusion; the bisulphate liquors contained no tin.

LOW-GRADE NIGERIAN CONCENTRATE—COMPARATIVE ASSAYS.

I. With titanium present 5 grm. charge in 500 cc. The TiO_2 in 100 cc. of assay liquor = 10 mg. The residues = 0·23 % tin.

a 100 cc. reduced with M. Comp. Co. nickel—15 minutes, 19·6 cc. iodine.

b 100 cc. reduced with Baird & Tatlock nickel—15 minutes, 19·6 cc. iodine.

c 100 cc. separated on zinc from titanium liquors, 19·65 cc. iodine.

% of tin calculated on *a* and *b* = 19·63.

II. With titanium removed by bisulphate fusion 5 grm. change in 500 cc. The TiO_2 in 100 cc. solution—nil. The residues = 0·26 % tin.

a 100 cc. reduced with M. Comp. Co. nickel—15 minutes, 19·6 cc. iodine.

b 100 cc. reduced zinc-nickel without separation, 19·6 cc. iodine.

% of tin = 19·66.

Whatever lingering doubts may remain as to the interference of titanium, there can be none when the tin is separated as metal and redissolved, but the conditions must be such that basic salts are not precipitated. In the synthetic studies of impurities—except for titanium—the conditions were those of the usual reduction with nickel, and for that reason the matter would be incomplete without similar experiments with reduction by zinc-nickel.

A stock solution of tin was used and solutions of sodium tungstate, copper sulphate and white arsenic were added so that the amount of tungstic acid, copper and arsenic oxide were known.

SYNTHETIC STUDIES OF THE EFFECT OF IMPURITIES—ZINC-NICKEL REDUCTION.

	Vol. of Tin Solution taken.	Weight of impurity added in milligram.	Nature of Reduction.	Iodine used in cc.
1	25 cc.	—	Zinc-nickel	16·9
2	100 ,,	—	,,	67·6
3	25 ,,	60 WO_3	Nickel	16·9
4	25 ,,	60 ,,	Zinc-nickel	17·2
5	25 ,,	60 ,,	Nickel	*17·0
6	100 ,,	60 ,,	,,	67·85
7	100 ,,	60 ,,	Zinc-nickel	68·60
8	80 ,,	150 ,,	,,	55·7
9	25 ,,	50 copper	,,	16·9
10	25 ,,	30 As_2O_3	,,	17·0
11	100 ,,	30 As_2O_3	,,	68·4

* 10 cc. more HCl used than in experiment 3.

With copper present within limits the reduction is more certain and there is no interference, but with amounts so large that the whole of the precipitated copper fails to re-dissolve in the acidified solution, some tin is retained and the titrations would be low, as in the case of the 'Burnt Leaving' concentrate.

Arsenic appears as a consumer of iodine notwithstanding the fact that the solutions were freely acid (55 cc. of HCl in a bulk of 155), and judgment on the effect of arsenic generally must be suspended. For the present it would be better to depend on facts based on experience. As a matter of prudence it would be better to remove other than small quantities. At this point it would be convenient to take what the author would prefer to call a study rather than an assay by the Pearce method. The material was a sample of slime concentrates; its source is not definitely known except that it is Cornish and probably prepared from the regrinding of tailings. Tungstic acid is for practical purposes absent (0·3 %), copper, arsenic and sulphur are present in small amounts. There was nothing in the appearance of the sample to suggest acid cleaning. A charge of 2·5 grm. was fused with sodium peroxide. For the purpose the nickel dish, 2 in. diam. was mounted in a sheet of asbestos millboard with a hole in the centre so that about $\frac{3}{8}$ in. of the dish projected above the millboard, which rested on top of a tripod. By this means the bunsen heat could be applied to the lower part, the upper part of the nickel crucible remained comparatively cold and creep of the

s avoided. The sodium peroxide was by measure, an A
ing cup full, of which about one-third was added to the
ish, the weighed charge was carefully transferred to the
nd covered with the remainder of the peroxide.
ish was covered with a piece of flat nickel about 2¼ in. square
ll bunsen heat applied till the mass had fused on top and
the charge; the bunsen heat was then raised nearly full
inutes. When cold the melt and lid were treated to dis-
stannate. In a suitable size beaker containing a mixture
. water and 30 cc. HCl, the lid cleaned first was free from
. The lid was removed with a slight wash with water, then
crucible with melt was carefully introduced into the
overed with a clock glass. The melt soon dissolved, the
removed after washing with a little water. A small
f cassiterite remained; it was recovered by filtration, and
solution of tin diluted to 250 cc. The residual cassiterite
d separately contained 7·5 mg. of tin = 0·3 % Sn. Two
of 100 cc. each of the stock tin solution were assayed for
by zinc-nickel reduction required 58·75 cc. iodine; (2) pre-
completely on zinc, filtered and re-dissolved, etc., required
odine. In both titrations a certain amount of sediment was
in the reduced liquor; each was a dirty liquor for titration.
second experiment the liquors, after titration, were filtered
fully washed. The recovered sediment by assay contained
tin. Thus, despite the concordance in the two titrations,
e undoubtedly low. The interference of tungstic acid is
ith zinc-nickel reduction, from the fact that reduction of
tic acid proceeds beyond the blue compound to the brownish
d. It has full effect in the Pearce assay, a variable effect
me assay according to the fineness of subdivision of the
in the sample. A sample of crop tin containing from
WO_3 was assayed by both methods. The Pearce assay on
charge with zinc-nickel reduction returned 70·75 %; the
y with zinc-nickel reduction returned 69·75 %, but it was
in this assay to remove the greater part of the tungstic
iltration, whereas in the Pearce assay it was not possible:
bility of the tungstic acid was *too* pronounced.

next example, a typical slime concentrate from the Red
ntaining 8·1 % WO_3 a Pearce assay gave 40·25 %, and a
ay 40·0 %, both on uncleaned material; on acid cleaned
without a complete removal of the wolfram a Pearce assay
65 %. In these three assays the reduction was with nickel

REFERENCE ASSAYS.—'ZINC-NICKEL' PERIOD—*continued.*

Sample No.	Buyers Assay.	Reference Assay.	Difference from Seller.	Sample No.	Buyers Assay.	Reference Assay.	Difference from Seller.
29	18·88	19·64 A	+ ·36	52	18·66	17·67 D	+ 2·33
30	18·89	19·95 A	+ ·05	53	18·75	19·69 C	+ ·31
31	18·51	19·44 A	+ ·56	54	18·36	18·86 D	+ 1·14
32	18·99	19·91 A	+ ·09	55	18·50	19·02 D	+ ·98
33	18·88	19·78 A	+ ·21	56	18·42	18·53 A	+ 1·47
34	18·80	20·6 C	− ·60	57	18·74	19·47 A	+ ·53
35	18·57	20·08 C	− ·08	58	18·70	19·24 A	+ ·76
36	18·86	20·00 A	± 0·	59	18·43	19·37 A	+ ·63
37	18·68	19·47 A	+ ·53	60	18·90	19·31 E	+ ·69
38	18·57	19·75 A	+ ·25	61	18·61	21·64 C	− 1·64
39	19·08	19·39 C	+ ·61	62	18·45	18·92 D	+ 1·08
40	18·39	20·86 C	− ·86	63	18·73	18·98 A	+ 1·02
41	18·44	19·35 E	+ ·65	64	18·03	18·8 C	+ 1·2
42	18·37	19·48 E	+ ·52	65	18·97	19·38 A	+ ·62
43	18·89	18·82 D	+ 1·18	66	18·80	19·31 A	+ ·69
44	18·63	19·61 D	+ ·39	67	18·71	18·71 E	+ 1·29
45	18·80	20·06 C	− ·06	68	18·63	19·03 D	+ ·97
46	18·72	20·22 C	− ·22	69	18·75	19·48 A	+ ·52
47	18·33	18·68 E	+ 1·32	70	18·43	18·6 C	+ 1·4
48	18·56	19·33 A	+ ·67	71	19·54	18·6 C	+ 1·4
49	18·78	19·75 C	+ ·25	72	18·56	19·09 C	+ ·91
50	18·23	18·63 E	+ 1·37	73	18·53	18·51 D	+ 1·49
51	18·63	18·86 D	+ 1·14				

With the reference assays as a general guide the change from nickel reduction to zinc-nickel reduction has eliminated low assays and incidentally brings the author in a general way above them. In the zinc-nickel period of some of these samples with the smaller range of difference it is possible to carry the investigation further. In an exchange of assays with one of the referees on a sample which needed no grinding there was complete concordance; but subsequently in an official capacity the same referee gave his verdict on a reference sample with about the average difference of 0·7 % lower than the seller. The referee afterwards admitted that the difference in part might be accounted for by the method used for the preparation of the sample for assay. It was coarser material than that on which the friendly exchanges had been made, and the procedure was such as would not have been adopted with richer material.

In another instance, where the product would pass a 200 mesh and wolfram was absent, the difference between seller and referee disappears with a re-assay by the seller on acid cleaned material—this being one of the rare instances where an assay was returned on

uncleaned material. Small but constant differences may arise on a point of standardizing: in the case of samples 29 to 73, standardizing with white arsenic lowers the seller's assays by approximately ·25 %. The simplest correction is to add −·25 to the proportional differences. Thus taking the first dozen in this list, which now read: +·36, +·05, +·56, + ·09, +·21, −·60, −·08, ±0, +·53, +·25, + ·61, −·86, corrected would read +·11, −·20, +·31, −·16, −·04, — ·85, −·33, −·25, +·28, ±0, +·36, −1·11, and the deviations from the mean value of seller and referee would be ·05, ·10, ·15, ·08, ·02, ·42, ·16, ·12, ·14, 0, ·18, ·55. All these small differences may be traced to slight differences in procedure, rather than to fundamental differences in the methods used for the assay. Some data relating to richer material may be given with advantage. Five consecutive parcels of black tin from the same mine were sold on the wet assay. Except for a small percentage of copper, there were no other impurities of importance. The assays for the seller were by the lime method, 2·5 grm. charges and zinc-nickel reduction; the assays for the buyers were by the Pearce method and by an assayer of long experience.

	Sellers Assay.	Buyers Assay.	Reference Assay.
Parcel I	67·4 %	64·85 %	67·75 %
„ II	69·15 %	68·75 %	—
„ III	69·30 %	68·75 %	—
„ IV	72·00 %	70·60 %	71·95 %
„ V	72·60 %	72·30 %	—

The variations in the assays made by the Pearce method are explicable by an occasional lapse with the nickel reduction method: failure to secure complete solution of the cassiterite with an experienced Pearce worker is very unlikely, whilst an error in grinding would be common to the whole series.

Although in a paper of this description imperfections figure prominently, there are good reasons for the hopeful statement at the commencement, that workers with a knowledge of the imperfections and weaknesses of the assays based on the iodine titration, will, if that knowledge is applied, return assays in agreement even when different methods are pursued. There are also good reasons for a belief that not only will there be concordance with methods based on the iodine titration, but that an experienced worker with the ferric chloride titration will agree with the worker with iodine.

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bject to revision.] [*A Paper to be discussed at a Meeting of the Institution of Mining and Metallurgy, to be held at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on Thursday, February 15th, 1917, at 5.30 o'clock p.m.*]

Hydraulic Tin Mining in Swaziland.

By J. Jervis Garrard, *Member*.

he Mineral Concessions now belonging to the Swaziland Tin, td., comprise an area of some 54,190 acres situated in the hilly ountry, in the North Western corner of Swaziland, which is the nly portion of that country in which minerals of value (with the xception of coal) have hitherto been discovered. The township of Mbabane, which is the capital of the country and seat of government, lies almost in the centre of the property and is about 90 miles by road from Carolina in the Transvaal, and about 90 miles from Goba, the terminus of the Portuguese Railway from Lourenço Marques to the Swaziland border, which railway was built with the intention of being eventually extended through Swaziland to connect with the Transvaal Railway system near Breyten, and so form the most direct route from the coast to the Rand. A map of the property (together with a key map) is shown in Fig. 1.

Geological.—Geologically the formation with which these alluvial deposits are associated is the older granite of the Eastern Transvaal. This rock where exposed as bedrock in various workings is found to be intersected by innumerable veins of pegmatite, quartz veinlets, nd occasional basic dykes of more recent origin.

The cassiterite undoubtedly owes its origin to the pegmatite eins, and quartz veinlets, which in the order given represent the atest stages of consolidation of the granite magma. That this is o is evidenced by the fact that in one working known as Sanders reek a big pegmatite vein occurred sufficiently decomposed to be apable of removal by hydraulicking, and a considerable amount of assiterite was recovered from this operation. Tin can be actually seen in thin pegmatites at Rowley and Stable Creeks, in veins varying from 2 to 8 ft. in width, and the author has also seen some big tin crystals embedded in pegmatite taken from a similar formation some 10 miles away. It may therefore be assumed that these tin deposits represent the effect of a natural concentration of the heavy constituents from the gradual degradation of the pegmatite veins in the granite, and along the numerous watercourses of this vicinity, where true alluvial deposits have been formed; whilst

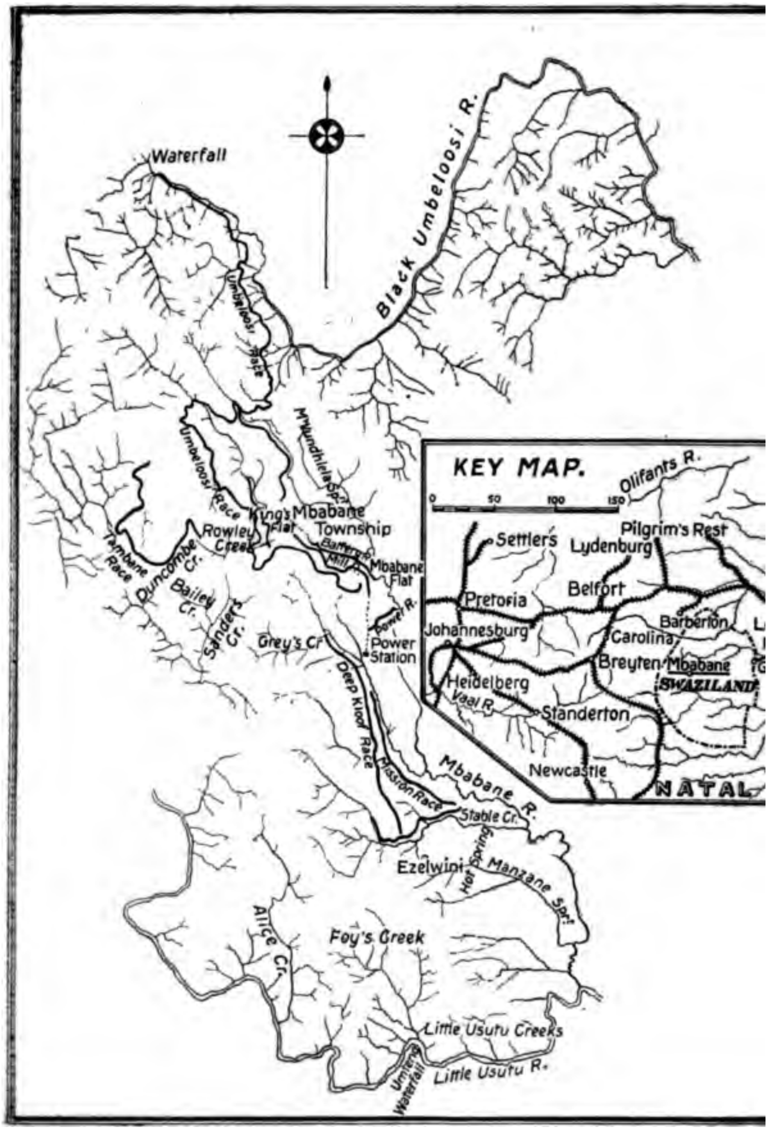


Fig. 1.—Property of Swaziland Tin, Ltd., and Key Map.

up the slopes of these valleys in places are found thinner deposits containing sharp-edged alluvial tin. The alluvial deposit proper consists generally of from 6 to 25 ft. of soft overburden, containing little tin, resting on from 6 in. to 3 ft. of coarse tin-bearing gravel, which in some places is associated with large boulders, the whole resting on the bedrock of granite which, as a rule, is much decomposed—so much so, in places, that not less than a foot of it becomes removed in the process of washing down the tin-bearing gravel to the elevating sumps.

Accessory minerals found in these gravels are ilmenite, monazite, euxenite, corundum, and tourmaline. Incidentally, a number of stone implements and arrow-heads have also been recovered.

Cassiterite crystals, as large as two inches across, have been met with in some of the higher-lying Hill Creeks, but the average size of grain of the bulk of the tin recovered from the 'Flats' is probably less than one millimetre.

Historical.—The four concessions under which this property is held were granted by King Umbandine of Swaziland in the year 1887. Little work of a serious nature was undertaken before the formation of this company in 1905. In the early stages of the company's existence work was almost entirely done on the 'tribute' system, the tributors being paid so much per ton of concentrate handed in by them. In July, 1906, the company took over the working of the mine on its own account, the method of operation consisting of ground sluicing, and the excavation of gravel by hand and sluicing it in small 16 ft. sluice boxes. This method was followed exclusively until 1908, when the company introduced hydraulic monitors. These were, however, only used for the removal of overburden, and the tin-bearing gravel was still excavated by hand and sluiced in the small boxes until 1911, when Mr. Douglas Osborne recommended the abandonment of existing methods and the introduction of hydraulic elevators to enable the deeper ground to be worked.

It will be understood from the nature of the method of working, how costly the production of concentrate up to this point must have been. Furthermore, owing to the impossibility of working ground below water level, the early miners contented themselves by working what they could, down to water level, and consequently left behind them a legacy of tailings covering up ground which succeeding workers have had to contend against. In other words, to-day in almost every working, the company is faced with having to re-work ground partially worked previously, too good to leave alone, and yet robbed of its primeval attraction through bad work in past years.

In 1912, the author was appointed consulting engineer and whilst recognizing the immense improvements brought about by the recommendation of Mr. Osborne, decided that even better use of the water supply could be made by utilizing the large amount of power then running to waste over the Mbabane Falls, making the waste power do the elevating by means of gravel pumps, and setting free so much more water for breaking ground. This scheme was brought into operation in July, 1913, and it is not too much to say that, but for it, the mines would have had to close down two years ago.

Physical features.—The various workings may be classified as follows:

(1) The 'Hill Creeks,' which are long, narrow creeks, situated high up in the mountains, at an altitude of some 4000–5000 ft. These creeks are for the most part worked by natural head hydraulicking during portions of the year when pressure water is available. The fall in the bed of the creeks is sufficient to carry away the tailing, so that elevating is unnecessary. The creeks include Sanders, Bailey, Duncombe, Rowley, Grey's, Ntamban, and Foy's creeks.

(2) The 'Flats,' which are the lower-lying valleys where the fall in the bed-rock is insufficient to carry away the tailing without elevating. These 'Flats' may be again subdivided into two portions, viz.:—

(*a*) King's Flat, Upper Mbabane Flats, M'Vundlehla Flats, situated close to the Township of Mbabane at an altitude of some 3500–4000 ft., and

(*b*) Stable Creek, Manzane Creek, and the Lower Mbabane Flats, situated some five miles south at an altitude of some 2000–2500 ft.

Water Supply.—The annual rainfall averages about 50 in. In the last ten years the minimum has been 36·46 in., and the maximum 72·83 in. The supply of water to all the Hill Creeks, with the exception of Foy's, is from the Ntamban Spruit, which is taken out high up in the mountains and carried in a water-race some seven miles long, through one tunnel, to a series of storage dams, from which it is distributed to the various creeks in subsidiary races. The amount of this water is about 225 cub. ft. per min. in the wet season, diminishing to about 20 cub. ft. per min. in the dry season. This water, after doing its work at Rowley Creek, is settled and used over again at Sanders Creek and Bailey Creek. The main supply to the flats is from the Mbabane River itself, which only rises some two miles above the upper working, supplemented by water taken out of the Umbelusi River and brought by a race some 14 miles in length to the main upper flats, where it is delivered

under a head of 150–300 ft. The full capacity of this race is about 1000 cub. ft. per min., but rarely is more than 800 cub. ft. per min. delivered during the wet season, whilst during the dry season this falls off to some 300 cub. ft. per min.

This water is, however, utilized to the utmost extent as follows:

(1) It is used under pressure in monitors to break ground in the Upper Mbabane Flat and King's Flat.

(2) After settlement in the big paddocks already worked out, it is caught up by another race and taken for use under pressure in monitors to break ground lower down at the Mbabane Flats.

(3) After settling it is caught up at the head of the Mbabane Falls (over which it previously ran to waste) and carried in a short race to the head-box of a pipeline some 2000 ft. long, where a portion of it is delivered under an effective head of 500 ft. to a Pelton wheel direct-coupled to an electric generator, which supplies the power necessary to drive the three gravel pumps; these elevate the gravel, which this same water has already broken down.

(4) After leaving the tail race of the Pelton wheel, this water, together with the overflow from the head box, is taken by another water race, carried some four miles farther on to Stable Creek, where it is again used for breaking ground, and, owing to the quantity being in excess of requirements, also for elevating the ground by means of an hydraulic elevator.

Thus the same water is used three times over for breaking fresh ground, and once for generating the power required to elevate the ground it has already broken.

Existing Methods of Working.

(1) *Drilling.*—In May, 1911, systematic drilling of the various flats ahead of existing workings by means of Empire drills was instituted with a view to arriving at some idea of the extent and value of the ground remaining to be worked. Altogether up to 30th June, 1915, 2341 holes had been drilled with a footage of 80,503 ft., costing 11¼*d.* per ft., including all transport. Recently the cost has been reduced to 5½*d.* per ft. At the above date 1,822,984 cub. yd., showing an average value of 1·44 lb. met. tin per cub. yd., were proved ahead of existing workings in addition to some 2,597,000 cub. yd. of ground in hill creeks estimated from results of past work (the ground being too bouldery for drilling) to be worth ·69 lb. met. tin per cub. yd., thus making a total of about 4,420,000 cub. yd. of an estimated average value of 1 lb. met. tin per cub. yd. *practically* assured, with a further extent of tin-

bearing ground amounting to 5,000,000 cub. yd., of which the quantity has been estimated, but the value not yet proved. Besides this, there still remains a considerable extent of ground over the enormous area of the concessions which has never been examined at all. Drilling is being continuously carried on. It has been found that the grade recovered from proved ground was considerably below the estimated grade, but this is explained by the fact that, in the actual course of working, ground outside the pay blocks as originally estimated was treated which, although of lower value, still paid to treat. This fact is important as, although rendering the attainment of the estimated grade indicated by drilling more or less illusive, it implies a considerable increase in the amount of ground to be actually treated, and a greater total recovery of metal in the aggregate. Where work has been strictly confined to ground drilled, with few exceptions (as in bouldery ground) the value recovered has been, if anything, more than that indicated by drilling.

(2) *Ground Sluicing.*—This method of working is employed only to a limited extent in places where no water or not sufficient water under pressure is available for hydraulicking. Such places occur chiefly in the upper portions of the hill creeks and on the slopes of the hills flanking creeks, where alluvial or 'terrace' tin is found. The method consists in leading all available water to the working paddock. A tail race is cut through the ground to be worked, and a feed race is cut at right angles to the tail race at the most convenient point on the upper side of the strip of ground to be worked. The water is then turned in, and both feed and tail races lowered to bedrock, if possible. Natives are then placed at 5 ft. intervals along the feed race, who undermine the bank ahead of them, so that the ground falls in big lumps into the feed race, where it is soon broken up by the water and carried down into the tail race. The feed race must always be kept just under the face, so that all ground picked down falls direct into the water and thus reduces the amount of handling to a minimum. Two or three natives, at intervals down the tail race, constantly throw out the larger stones with forks, and a rough concentrate is periodically thrown out from the race to be afterwards dressed down in small boxes, 16 ft. long by 18 in. wide, to a grade of about 58% met. tin, in which state it is transported to the main dressing plant. In the case of ground lying on a steep slope, the whole of the gravel is washed down the steep tail race for concentration as above in another tail race, in the creek below.

In places where water is scarce the gravel is shovelled direct into the small boxes above referred to.

Only about 9 % of the total ground handled is treated by this method. The cost of working is much higher than for hydraulicking work, and the amount of ground treated in a given time is, of course, much less.

(3) *Hydraulicking under natural head without elevating.*—The only workings where it is possible to employ this ideal method are in the following Hill Creeks, viz.:—Sanders, Bailey, Duncombe, Rowley and Foy's, and it is only during the wet season of the year that this is rendered possible, owing to the falling off of the water supply.

Water races are led from the upper storage dams, along the sides of the hills flanking these creeks. At convenient places head boxes are constructed, and 8-in. to 12-in. pipes are laid down the hill slopes to the bed of the creek below, where the water is used in monitors through 1¾-in. to 2½-in. nozzles to break down the banks. The nozzle pressure varies from about 55 lb. to 80 lb. per sq. in., and the height of bank from 6 ft. to 14 ft. No sluice boxes proper are used in these creeks, the tin concentrate being collected in the tail races, which are periodically cleaned up and the resulting rough concentrate is dressed in small boxes 16 ft. long by 18 in. wide to a grade of about 58 % met. tin, in which state it is transported to the main dressing plant. This method accounts for about 30 % of the total ground handled, and the total cost of work by this method, including head office charges, amounts to 4·895*d.* per cub. yd.

(4) *Hydraulicking and Gravel Pumping.*—This method of working is the principal one in vogue and accounts for about 44 % of the total ground handled. It is employed at the Upper and Lower Mbabane 'Flats' and at King's Flat.

The method employed is as follows: The water from the Main Mbelusi Race is led along the slopes of the hills which flank the 'flats' at a level of from 150 ft. to 275 ft. above the bed of the valley. At a convenient point in the race opposite the position of the working a head box is constructed from which a pipeline consisting of 12-in. to 22-in. pipes is laid down the hill slope to the working paddock. Branch pipes are taken off from the lower end of the main line and led, as convenience dictates, to the different working faces, where the water is used through monitors or giants to break down the face of the paddock and banks. The pressure at the nozzles varies from about 55 lb. to 110 lb. per sq. in., 2-in. to 2¼-in. nozzles being used. The ground thus broken down is led into a temporary race in the bedrock to the sump of the gravel pump. If the fall is slight a monitor is used to blow the

gravel to the sump. A few natives fork out of this race some of the larger stones and small boulders. The gravel pump (described in detail later) direct-coupled to its motor rests on a pontoon 20 ft. square. This when at work rests on the bedrock. A movable suction pipe takes the gravel from the sump and the delivery pipe discharges it at an angle of some 45° into a launder, supported on trestles, which leads to the sluice boxes placed at a convenient point on the bank above the general surface level. The height lifted is from 38 ft. to 40 ft. The launder usually discharges on to an inclined grizzly over the head of the sluice box, the oversize, consisting of stones and small boulders, being delivered direct into a truck which is trammed to the dump. The undersize falls into the head of the sluice box, which varies from 8 ft. to 11 ft. in width and 80 ft. to 100 ft. in length, set to a grade of 1 in 25, and is constructed of steel plates bolted together. The side plates, 3 ft. high, have angle iron slots at intervals of 8 ft. into which 3-in. by 3-in. deals are dropped to form riffles.

The amount of gravel elevated averages 24 cub. yd. per hour, the amount of water pumped varying from 190 to 280 cub. ft. per min. Additional water (not under pressure) is usually led in the head of the sluice box to assist in sluicing the gravel through the box. Six to eight natives are constantly employed in the upper half of the sluice box, loosening the gravel with forks and maintaining an even surface. As the bed of gravel accumulates in the box it is thinned down by stopping the supply of fresh gravel, and the rough concentrate from the upper portion of the box is shovelled out to the side periodically, and at the close of each month the box is completely 'streamed down,' the gravel from the lower part of the box being continually shovelled up the box against the stream of water when the remaining concentrate is finally shovelled out. The rough concentrate thus produced is streamed down in small boxes about 16 ft. long by 18 in. wide, by natives constantly shovelling it up against the stream. Three natives are employed on each box, and they can treat from 12 tons to 15 tons per day according to the richness of the rough concentrate handled. This process brings the concentrate up to a grade of about 60 % met. tin, in which state it is sent to the central dressing plant.

The average labour complement for each gravel pump working is 55 natives and one European overseer for 24 hours. It was necessary to have a European overseer on each shift at the start and for some months after; but gradually it became possible to train natives to do the whole work efficiently. In fact, one

European overseer has been able to look after two gravel pumping plants half-a-mile apart for several months past.

Each plant is equipped with electric light for night work, and is in telephonic communication with the power station and with the mechanical staff. When it is desired to shift the pontoon to a new site nearer the working face, a cut is made in the face of the paddock near the new site for the sluice box. This cut is made just wide enough to allow the pontoon to pass. When the new site for the pontoon is reached, the cut is widened and the site levelled and beaconed off with long poles. The whole paddock is then flooded to a depth sufficient to enable the pontoon to be floated through the cut to its new position. This being accomplished, a sod dam is built behind the pontoon across the narrow cut, and a water lifter (described later) is used to pump out the water in this small paddock now formed, when the pontoon settles on the new site prepared for it and work is resumed as before. By this method much time is saved that would otherwise be spent in pumping out some 3 ft. of water from the whole area flooded. The average time lost through this operation of removal is 100 hours. Another sluice box has, in the meantime, been constructed in a convenient position for the new site, and alterations or extensions to the power line and pipelines have been made in anticipation of the removal.

It occasionally happens that owing to physical conditions, such as too great difference of level, or the necessity of removal to a site too far away to make flotation possible, it becomes necessary to dismantle the whole plant, transport it to the new site and re-erect it there. The time lost over such an operation is about 20 days, and the cost amounts to about £250.

The general policy adopted in this class of work is always to operate up stream as far as possible, allowing the tailing to fill up the previously worked out paddocks. It may sometimes happen, however, that circumstances dictate the advisability of working down stream to a small extent, and in that case, if there is still workable ground below, it becomes essential to arrange matters so that the tailing shall not be allowed to cover up this ground, either by conducting the tailing in a race cut specially to by-pass it beyond the workable ground below, or by selecting some position of unworkable ground, if it exists, building a rough dam round it, and conducting the tailing into this dam. The total cost of working by this method, including head office charges, amounts to 8·229*d.** per cub. yd., which includes ·482*d.* per cub. yd. for power.†

* See last paragraph under *Hydraulicking and Hydraulic Elevating*, p. 13.
† See *Figs. 2, 3 and 4 (Plates I and II).*

(5) *Nozzle Pumping and Gravel Pumping.*—This method of working has been employed in the case of one gravel pump at Mbabane Flats working portions of four months of the dry season, when there was insufficient water under natural head available at this point to supply the gravel pump.

The method employed is as follows:—a two-stage centrifugal pump direct-coupled to a 100 hp. motor, is mounted on the same pontoon as the gravel pump. It takes its suction from the creek water in the cut which diverts it from the paddock, and delivers 115 cub. ft. per min. through a $1\frac{3}{4}$-in. nozzle at a pressure of 100 lb. This pressure water serves the same purpose in breaking down the ground that the water under natural head does when that water is available, and the genera arrangements and method of working are exactly the same as those just described. The power consumed by this nozzle pump amounts to about 68 units per hour. The cost of working by this method is practically the same as in the case of hydraulicking and gravel pumping.

The method possesses many advantages if cheap power is available. It often saves the construction of new races, and the laying and constant shifting of long pipelines frequently in difficult positions, even when high pressure water under natural head is available; whilst, as will be seen, it is invaluable when this is not available. It is, in fact, probably preferable in certain cases to employ high pressure water under natural head at one permanent point for the generation of power, and to utilize such power for the purpose of carrying out this method of working; its convenience and simplicity are of course obvious and are largely due to everything being concentrated in one self-contained unit which is floated from place to place.

(6) *Nozzle Pumping without Elevating.*—This method of working has been employed high up in the hills in Grey's Creek, at which point tin-bearing gravel was found to exist where no water under sufficient natural head could be spared for hydraulicking. The method employed is as follows:—A dam is constructed across the creek below the working, with arrangements to enable the accumulation of tailings to be sluiced out periodically. One or more subsidiary settling dams connect with this to enable comparatively clear water to pass to the suction of a two-stage centrifugal pump driven by a 100 hp. motor. The pump delivers about 74 cub. ft. per min., through a $1\frac{1}{2}$-in. nozzle at about 75 lb. pressure, that at the pump being 85 lb. The length of the delivery varies from 200 ft. to 600 ft. from the pump, and the height from 15 ft. to 25 ft. above the pump. The gravel is broken down by this pressure

as in the case of natural hydraulicking, the tailing settling in wer dam, until sluiced out at intervals, and the water being ed to the pump suction. About 7000 cub. yd. have been cut onth at a cost of 9*d.* per cub. yd., actual creek cost, or 11*d.* ıb. yd., total cost. The average rate of cutting is about b. yd. per actual hour run, the power consumption being 60 units per hour, equivalent to a duty of about ·35 cub. yd. r unit.

natural flow in the creek itself is about 20-30 cub. ft. per but as it is always endeavoured to maintain a more or less nt flow of thick pulp of tailing water by the bottom outlet ;h the dam wall, the whole of this natural flow does not repre- ıe true amount of make-up water used. If the configuration surface permitted it, the sluicing out of the tailing would necessary, as the extent of the dam would then be simply ed and its depth increased, or another dam constructed higher creek, which would put a suction head on the nozzle pump. motor at the working referred to became badly damaged by ing, it was decided to stop this method of work and leave mainder of the gravel to be recovered by natural hydraulicking the water now being used at other places becomes available course of time. This method of working is, however, quite le and has also been successfully used by the author at the fontein Tin Mines in the Waterberg Distric of the Transvaal, he difference, however, that every drop of make-up water had it case to be pumped four miles and lifted about 1200 ft.; ydraulicking being carried on at the top of a hill by of a seven-stage centrifugal nozzle pump circulating the at that elevation, and the power being derived from a gas and bituminous gas plant at a cost of ·65*d.* per unit.

Hydraulicking and Hydraulic Elevating.—The only working this method is now carried on is at Stable Creek, the lowest ıg on the property. It accounts for about 17 % of the ;round handled. The method employed is as follows:—The from the upper gravel pump workings after generating c power at the power station is caught up in a race and l some four miles along the hill side to a point opposite this ıg, when it is conducted down a pipeline which leads a n of it to one or more monitors, and the balance to the ulic elevator. Some 212 cub. ft. per min. at a pressure of are employed for breaking the ground (the height of the bank ;ing about 18 ft.). The broken ground falls to the sump of 2-in. elevator, which takes about 330 cub. ft. per min. at

55 lb. pressure, the average size of jet being 3·47 in. and average diam. of throat 6·55 in.

The average height lifted is 23·3 ft., the 12-in. delivering pipe discharging into a sluice box 11 ft. wide, 100 ft. long, set to a grade of 1 in 30. The amount of ground elevated averages 24·4 cub. yd. per hour, and the total volume of water used amounts to 1302 cub. ft. per cub. yd. of ground removed, of which 490 cub. ft. are required per cub. yd. of ground broken down by monitors, so that the elevator consumes 62·2 % of the available water (under 55 lb. pressure) for its operation, leaving only 37·8 % available for breaking ground. As, however, there is more water available here than is required to do the work, its inefficient use is not of moment. Moreover, as already pointed out, this same water has already been twice used for breaking ground in the upper workings of the property, and once again for generating electric power before doing its work at this creek, so that a little generosity over the matter of efficiency can be well afforded here, especially when the extraordinary simplicity and reliability of this most useful device is taken into consideration. Given a surplus of water under pressure, there is nothing to touch this device; but it is most wasteful otherwise, as it will be seen later that the gravel pumps actually performed 64 % more useful work than the hydraulic elevator for a given quantity of water power.

Careful statistics, kept over twelve months ending 30th June, 1913, showed that the four hydraulic elevators then in use took for their operation on the average 73 % of the total water available, leaving only 27 % for useful work in breaking ground by monitors. The best monthly performance of any one elevator showed 60 % elevator water to 40 % monitor water, and the worst, 84 % elevator water to 16 % monitor water. Moreover, all the best high-pressure water has to be used on the elevators to obtain the necessary lift. This implied, therefore, that by setting free this elevator water at King's Flat and Mbabane Flats and elevating the ground by means of gravel pumps there would be nearly four times as much water available for use in monitors breaking ground, and, furthermore, this water being under a high pressure it would be capable of more efficient work.

The lighting of this working, in common with other workings far removed from the main electric power lines, is accomplished very successfully by means of a small generating set consisting of a generator direct-coupled to a water motor, which derives its power from a branch pipe taken off the main pressure pipeline, and consumes 15 cub. ft. of water per min.

The total cost of working by this method, including head office charges, amounts to 6·276*d*. per cub. yd. This compares with 8·229*d*. for gravel pumps, but it should be mentioned that over the period in question the hydraulic elevator was working principally in deep, soft virgin soil, whereas the gravel pumps worked ground from which most of the material had been washed away in previous years.

Given the same ground, it is probable that gravel pumping would not cost more than 6*d*. per yard, as the capacity of the pumps is greater.*

Description of Plant.†

Power Station.

Pelton Wheel.—This is capable of giving off 300 hp. when working under an effective head of 500 ft. of water; average consumption 430 cub. ft. of water per min.; speed 500 rev. per min. The Pelton wheel is fitted with two nozzles, each controlled by a valve, and the speed regulation is obtained by a sensitive oil pressure type of governor. The governor controls the speed of the wheel by means of deflectors which divert the water jet from the wheel. The speed variation is guaranteed not to exceed 3 to 4 % from no load to full load and this guarantee has been well maintained. The governor is driven off the Pelton shaft by means of a chain drive. The water supply is derived from a race which collects water which has already been twice used for hydraulicking work in the upper Mbabane Flats. A pipeline varying from 24 in. to 12 in. diam. leads the water for 2000 ft. down the slope of the hill at an effective head of about 512 ft.

Generator.—250 K.V.A. three-phase, direct-coupled to the Pelton wheel by flexible coupling of the Zoedel type, generating current at 550 volts, 50 cycles per sec. The exciter armature is carried on an extension of the generator shaft, and the field coils of the exciter are supported by the outside pedestal bearing. The exciter is capable of supplying the exciting current necessary for the output of the generator, plus 1 K.W. which is required for lighting the generating station. The switchboard controlling generator and exciter is equipped with ammeters and voltmeters, watt-hour-meter and field regulators. To connect the generator to the power line a three-phase oil switch with overload release coils is used. The

* See Fig. 5 (Plate II).

† *Transvaal S. A. Inst. Electrical Engineers.* March, 1915. 'Notes on the Electrical Plant, Swaziland Tin, Ltd., Mbabane,' by W. Elsdon Dew, M.I.E.E.

step-up transformer is of 250 K.V.A. capacity, the current being stepped up from 550 to 3300 volts. The line can be isolated from the transformer by links.

During the year ending 30th June, 1915, the generating station ran 95 % of full time, generating 760,534 units at a cost of 0·3672*d.* per unit, including all maintenance charges on the plant and main water race; but the load factor was only ·4283.

Power Line.—This consists of stranded aluminium wire 7/·114 size equivalent to No. 4 S.W.G. copper. The length of the principal line is approximately four miles, and it is carried by poles of blue gum. The methods adopted for jointing and stringing the wires are those advocated by the manufacturers and are perfectly satisfactory. The lines are protected with horn arresters at their extreme ends and also at intervals along the line. A water jet arrester is also installed at the generating station end.

This was the first installation of an aluminium power line of any importance in this country, and on comparing the relative cost of the aluminium conductor as against copper wire it was found that there was a saving of approximately 22 % in favour of aluminium at that time, considering the cost of conductors only. The supports of conductors and handling of the aluminium wire cost something more than if copper had been used, but the experience gained has quite justified the use of aluminium and there have been no troubles with the aluminium conductors.

Gravel Pumps and Motors.—The pumps in use are 8-in. centrifugal pumps, specially constructed for this class of work, having renewable shoes on the impellers and renewable linings in the casings. The pumps are direct-coupled to 50 hp. motors running at a speed of 485 rev. per min., and deliver water and gravel to a total height of 40 ft. A swivel joint is employed to raise or lower the suction pipe, and in order to avoid the necessity of shifting the pontoon so frequently, the suction pipe is at times extended to as much as 300 ft. from the pump. The arrangement of the suction door in use at the end of the suction pipe is shown in Fig. 6.

The motors are supplied with current at 200 volts from a step-down transformer, the whole equipment, including switchboard and wattmeter, being fixed on a wooden pontoon of substantial construction about 20 ft. square.

This is made watertight and has a displacement sufficient to enable it to be floated when necessary. It is roofed in and enclosed on three sides to protect the electrical apparatus from the weather.

The pontoon during ordinary working operations rests on a flat

portion of the bedrock prepared for it, the suction pipe being taken to a suitable sump cut out of the bedrock, while the delivery pipe is taken out through the roof at an angle to the head box which feeds the sluice box. The overhead power line is brought to within a distance of about 60 yd. of the pontoon, and a cable is connected to the line by means of controlling links and connected through oil switches, etc., to the apparatus on the pontoon.

During the year ending 30th June, 1915, the three gravel pumps ran 70·9 % of the time that power was available, elevating 420,248 cub. yd. of ground (averaging 24 cub. yd. per hour) or 0·76 cub. yd. per unit, the average height lifted being 38·6 ft.

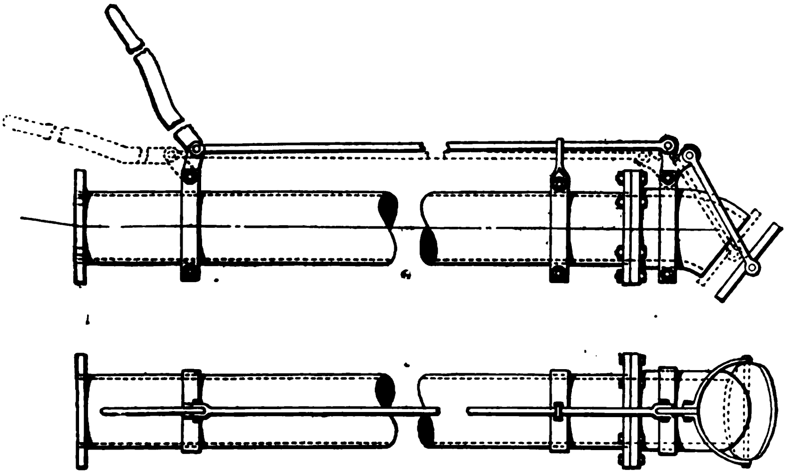


FIG. 6.—Arrangement of Suction Door, Gravel Pump.

The cost per running hour on these pumps averaged over the year 11·5*d.* (elevenpence halfpenny) for power, 5·3*d.* for renewals, and 4·3*d.* for repairs. The average efficiency of the three pumps on the whole year's run was 27·35 %, compared with 24·3 % for the previous year. The normal staff for each gravel pump working consists of one overseer and 165 natives per day of three shifts, though latterly two of the gravel pumps have been run by only one overseer.*

Nozzle Pumps.—(1) The nozzle pump, which is erected on the same pontoon as the No. 1 gravel pump, consists of an 8-in. two-stage centrifugal pump capable of delivering 144 cub. ft. per min.

* See Figs. 2, 3, and 4.

against a manometric head of about 200 ft., at a speed of 1450 rev. per min., direct-coupled to a 100-hp. three-phase 500 volts motor.

(2) The nozzle pump at Grey's Creek consists of an 8-in. two-stage centrifugal pump capable of delivering 152 cub. ft. per min., against a head of about 250 ft. at a speed of 1700 rev. per min. This pump was belt-driven by a 3000 volts motor at 600 rev. per min.

Hydraulic Elevator.—Various types of elevator have been tried from time to time. The results of four years' experience, however, show that the modified type shown in Fig. 7, as designed on the mine, gives the best results.

Different sizes of jet and throat are used according to the amount of water and pressure, but as a rule a 3½-in. jet and 6½-in. throat are employed with a working pressure of about 55 lb., which is equivalent to 330 cub. ft. of water per min. of pressure water through the jet. This water lifts the monitor and seepage water, amounting to about 226 cub. ft. per min., plus 11 cub. ft. of gravel per min., to an average of 23·3 ft. to the sluice boxes. The efficiency of the elevator calculated over the whole year ending 30th June, 1915, was 16·58 %, compared with 15·2 % for the previous year. The normal staff for this hydraulic elevator working is one overseer and 183 boys per day of three shifts.*

Water Lifter. — This simple device, which is made out of standard pipe fittings, is shown in detail on Fig. 7, together with a sketch showing the method of applying it. Its action is similar to that of an ejector.

Monitors.—Various types of monitors have been tried and various types are in actual use, but the one which has been found to give most satisfaction is shown on Fig. 8, designed on the mine by Mr. H. M. West.†

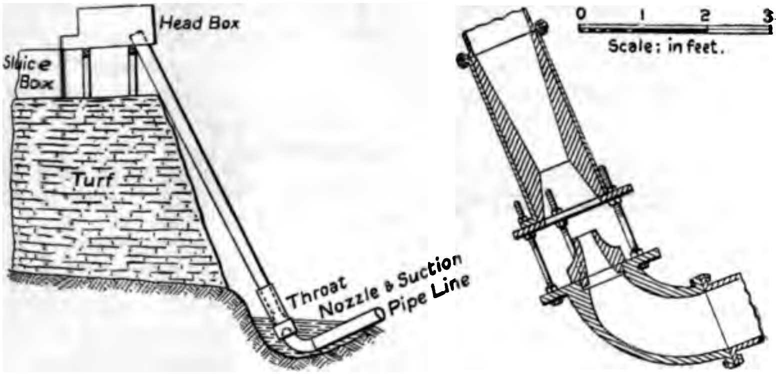
Richards Hydraulic Riffle and Jig.—Experiments are now in progress with a view to ascertaining whether it is possible to utilise a combination of these machines to replace the ordinary sluice box, and thus save the handling and dressing at present entailed.

Dressing Plant.—The tin concentrate roughly dressed at the various workings varies in grade from 46 % to 64 % metallic tin according to the varying proportion of iron sand contained. This is always higher where the tin is finer, in the lower lying flats, than where the tin is coarse, in the hill creeks. The concen-

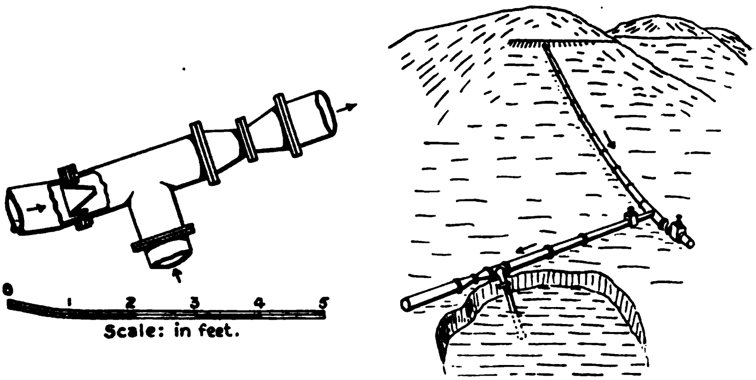
* See Fig. 5 (Plate II).

† See also Fig. 2 (Plate I).

trate in its rough state is transported in carts or on pack mules from the various workings to the central dressing plant. Here it is redressed, the coarse in hand jigs and the fine in inclined boxes under a running stream of clear water, to remove any re-



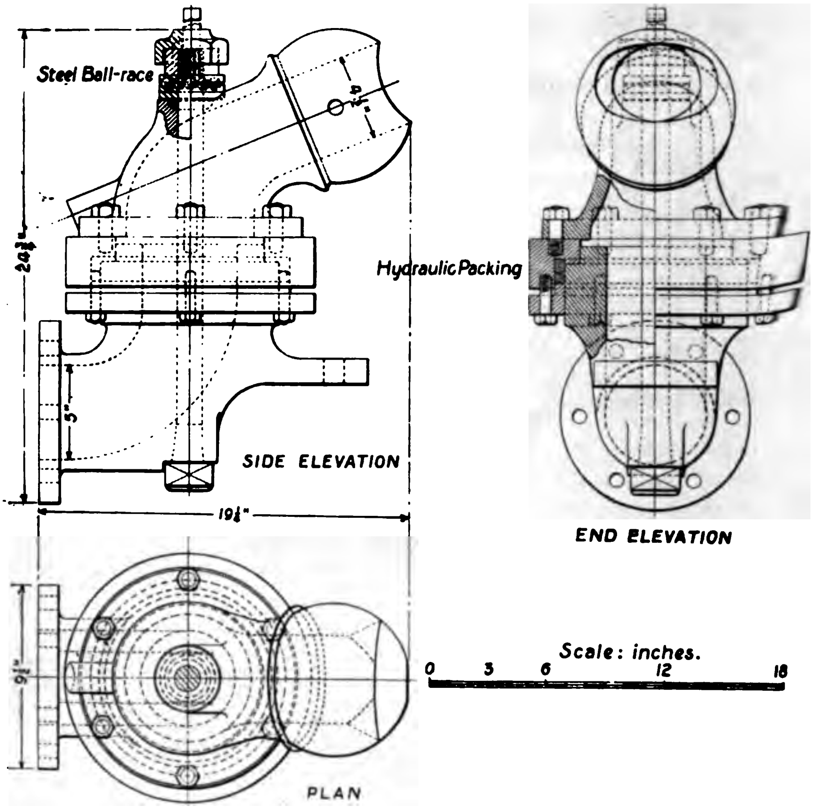
Hydraulic Elevator.



Water Lifter.

FIG. 7.—Details of Hydraulic Elevator and Water Lifter.

maining lighter material. It is then dried by spreading on large inclined trays exposed to the sun's heat in dry weather, or on hot plates heated over wood fires in wet weather. The concentrate is then passed through a Wetherill magnetic separator which



Monitor with Packing Glands.

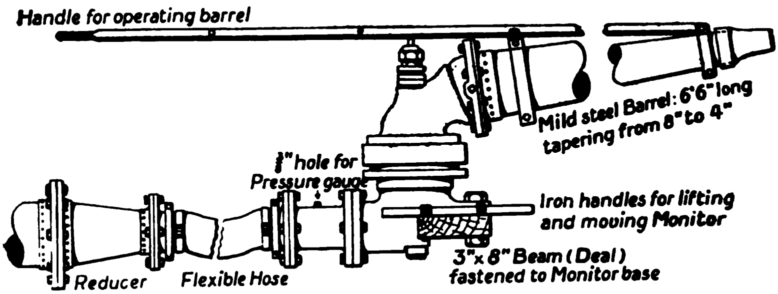


FIG. 8.—General arrangement of Monitor as connected for working. When working on high pressures flexible connection is dispensed with and the *Monitor* is connected direct with Reducer on Pipeline.

effectually removes the remaining impurities, consisting chiefly of ilmenite. It is then weighed, sampled and assayed and bagged for shipment. The average grade shipped varies from 71 % to 72 % met. tin. The dressing plant is in charge of the tin dresser, with 16 natives, who are also used for loading and unloading wagons and occasionally for road repairing.

Workshops.—These consist of blacksmiths' shop, fitters' shop and carpenters' shop, equipped with the usual tools driven by an electric motor. The system adopted in the organization of work on this property is, that the electrical and mechanical staff are entirely responsible for the maintenance of all units of the plant in constant good repair and running order. The overseers at the workings merely run the machines for the purposes of their work; but it is the business of the mechanical staff to see that these machines are always kept in good order. Each pontoon is connected by telephone with the central depot. It is, of course, necessary to keep a considerable stock of spare parts on hand, and also that the workshop equipment and staff should be capable of carrying out all ordinary repair work, seeing that the nearest railway station is 90 miles, and the nearest workshop 140 miles, distant.

The mechanical staff consists of a working electrical and mechanical engineer-in-charge (Mr. H. M. West), one electrician, one fitter and one carpenter and seven natives.

EFFICIENCY DATA.

Basis of Efficiency Calculations.

Gravel Pumps.

$$E = \frac{0{\cdot}65 \times \text{ft. lb. per min. lifted}}{\text{ft. lb. per min. of power required for work.}}$$
$$= \frac{0{\cdot}65H\,(62{\cdot}3\,W + 100\,S)}{44240\,U} \text{ or } \frac{0{\cdot}65H\,(62{\cdot}3\,W + 45\,G)}{44240\,U}$$

where E = Efficiency.
H = Height in ft.
S = Cubic ft. per min. of solids lifted.
W = Cubic ft. per min. of monitor water + seepage or added water lifted.
G = Cubic yd. per hour of gravel lifted.
U = Units consumed per hour (1 unit = 44,240 ft. lb. per min. for one hour).

(Note.—85 % is allowed for electrical transformation and transmission losses from the head box of power plant to current put into motors at pumps.)

Hydraulic Elevators.

$$E = \frac{\text{ft. lb. per min. lifted}}{\text{ft. lb. per min. required for work.}}$$

$$= \frac{H\ (62{\cdot}3\ W + 100\ S)}{62{\cdot}3\ N\ (H_1 - H)} \text{ or } \frac{H\ 62{\cdot}3\ W + 45\ G)}{62{\cdot}3\ N\ (H_1 - H)}$$

where E = Efficiency.
H = Height lifted, in ft. above elevator nozzle.
H_1 = Effective head of pressure water in ft. above nozzle.
W = Cub. ft. per min. of monitor water and seepage, or added water lifted.
S = Cub. ft. per min. of solids lifted.
G = Cub. yd. per hour of gravel lifted.
N = Cub. ft. per min. of pressure water through elevator nozzle.

In order to show how this works out in practice the following examples of the average results of working over the whole year ending 30th June, 1915, are appended:—

No. 3 Gravel Pump—King's Flat.—Average diam. monitor nozzle 2·3 in., average nozzle pressure 104·2 lb. Monitor water, 202·7 cub. ft. per min. Seepage water, 9 cub. ft. per min. Water run in from creek to assist monitor, 14 cub. ft. per min. Gravel lifted, 24·6 cub. yd. per hour. Total height lifted, 40·2 ft. Units consumed, 31·89 per hour.

$$E = \frac{0{\cdot}65 \times 40{\cdot}2\ (62{\cdot}3 \times 225{\cdot}7 + 45 \times 24{\cdot}6)}{44240 \times 31{\cdot}87} = 0{\cdot}281$$

$$= 28{\cdot}1\ \%\ \text{efficiency.}$$

12 in. Hydraulic Elevator—Stable Creek.—Average diam. monitor nozzle, 2·77 in. Average nozzle pressure, 55 lb. Monitor water, 212·3 cub. ft. per min. Seepage water, 11 cub. ft. per min. Water run in from creek to assist, 3 cub. ft. per min. Average diam. elevator nozzle, 3·47 in. (throat 6·55 in.) Average pressure on elevator nozzle, 55 lb. = 127 ft. effective head. Elevator water, 330·4 cub. ft. per min. Gravel lifted, 24·4 cub. yd. per hour. Total height lifted, 23·3 ft.

$$E = \frac{23{\cdot}3\ (62{\cdot}3 \times 226{\cdot}3 + 45 \times 24{\cdot}4)}{62{\cdot}3 \times 330{\cdot}4\ (127 - 23{\cdot}3)} = 0{\cdot}1658$$

$$= 16{\cdot}58\ \%\ \text{efficiency.}$$

The average efficiency of the three gravel pumps on the year's run was 27·25 % (compared with 24·3 % for the previous year) as against 16·58 % for the hydraulic elevator (compared with 15·2 % for the previous year). So that the electrically-driven gravel pumps actually performed 64 % more work than the hydraulic

elevator for a given quantity of water power. A further check on the current working results is the monthly record kept of the number of cub. yd. of gravel elevated per unit. This for the year in question amounted to an average of 0·76 cub. yd. per unit consumed.

The weekly log sheet is shown in Appendix A (where, however, it is given filled in with the actual figures recorded for the whole year ending 30th June, 1915). The units generated at the power station are recorded and on each pontoon the units consumed by the pump motor are also recorded. The time the pump is working gives a figure showing the average consumption per hour, while each week a check is taken for one hour when the pump is kept fully supplied with gravel and water. This figure gives a maximum load which the pump should do regularly and from this a figure, which is practically the load factor of the unit of plant, is obtained. The overall factor of the whole operation is also useful check for the management to see how the work varies.

The monthly record of work is shown in Appendix B (where, however, it is given filled in with the actual figures recorded for the whole year ending 30th June, 1915.

It will be seen that this gives a very complete picture of the month's (or year's) operations and enables the management to see how things are going from time to time. As the main basis of calculation is the number of cub. yd. of gravel cut in a given time, careful surveys are made at the middle and at the end of each month, at each working place. It is found that the keeping of all the data necessary for the preparation of these records is amply justified by the results obtained, adding materially to the general efficiency of all operations.

Appendix C shows the nozzle table and formula which forms the basis of water measurement through nozzles. Weir gauges are fixed at all the principal points in the various water races to measure the main ources of supply.

Working Results.—The results and costs of working for the whole year ending 30th June, 1915, are very fully set out in the record of work shown in Appendix B. 961,550 cub. yd. of ground were treated or an average of 80,129 per month. 1·004 lb. of concentrate of a grade of 71·253 % met. tin was recovered per cub. yd. giving an average of ·715 lb. met. tin recovered per cub. yd. The Creek working costs were 4·81*d*. per cub. yd., the total mine costs being 6·013*d*. per cub. yd., and the total cost, including head office charges, 6·597*d*. per cub. yd.

The amount of water consumed by monitors in cutting ground

for gravel pumps was on the average 166·2 lb., to which were added 86·8 cub. ft. per min. at an average pressure of 88·2 lb., to which also were added 86·8 cub. ft. per min. run in from creeks to assist monitors, whilst in addition 12 cub. ft. per min. of seepage water were elevated, the total consumption of water being 492 cub. ft. per cub. yd. of ground elevated by the gravel pumps.

In the case of the hydraulic elevator 490 cub. ft. of water were required per cub. yd. of ground broken by monitors at an average pressure of 55 lb., the total consumption being 1802 cub. ft. per cub. yd. of ground elevated.

In the case of hydraulicking operations in the Hill Creeks the amount of water consumed by monitors in cutting ground was on the average 219 cub. ft. per cub. yd. of ground recovered, at an average pressure of 69 lb. The performance of the three grav pumps after constant wear and tear of the roughest description i elevating sand, gravel and boulders (up to the size of a man's hea ever since their installation in July, 1918, is truly remarkable, tl pumps being still in perfect condition.

When it is considered that this property has yielded such go profits for so many years by means of methods which can only described as primitive to the last degree, some idea of the phenome richness of the original alluvial gravel may be gathered. T author's only regret now is that this original virgin ground is longer available; as with existing methods and cost of working, is evident that such ground would have yielded enormous profi Fortunately, however, although rendered more costly to recov owing to the superimposed legacy of tailings, there still remains large quantity of tin lying below water level which the form workers with their primitive methods were unable to reach.

General.—The design and erection of the electrical equipme was ably carried out by Professor Heather and Mr. Elsdon De Considerable credit is due to the Mine Manager, Mr. T. Kelly, f having been able to train the raw natives of Swaziland to carry o operations, which require no small amount of skill, with tl minimum of European supervision, thereby reducing the cost working at this mine to what may be considered a very reasonab figure. Mr. Kelly is assisted by a Surveyer, Mr. W. T. Mol who is responsible for the measuring up of all workings, wat calculations, the preparation of all records and statistics ar assaying.

The office staff consists of a mine secretary, and a timekeeper wl is also responsible for stores.

The Company supplies electric current for lighting purposes

the Mbabane Township free to Government offices and officials and for street lighting, and at a nominal charge to other residents. It has also provided for the water supply of the Township from its main water race. Such facilities in an out-of-the-way place like Mbabane are much appreciated and tend to maintain the relations between the Company and the Government and residents on the cordial footing which has always existed.

*** *Extra Copies of this paper may be obtained, at a nominal charge, at the Offices of the Institution, 1, Finsbury Circus, London, E.C.*

Crowther & Goodman, Ltd., Printers, 124, Fenchurch Street, London, E.C.

—No. 3 Gravel Pump, Upper Mbabane Flat. Monitor blowing down
·l to sump of extended suction pipe. Umbelusi Race on distant hills.

3.—No. 2 Gravel Pump, King's Flat, showing general arrangement.
·r blowing down gravel to sump. Main Umbelusi Race is visible in top
·d corner of picture.

:o. 3 Gravel Pump, Upper Mbabane Flat. Monitor blowing down o sump of extended suction pipe. Umbelusi Race on distant hills.

-No. 2 Gravel Pump, King's Flat, showing general arrangement. lowing down gravel to sump. Main Umbelusi Race is visible in top corner of picture.

	CAUSE OF STOPPAGES.
Generating Static	dams, general overhauling of plant. actor ·78, transmission losses 12¼ %.
Mbabane Flats N Gravel Pump	vork, rebuilding and floating pontoon.
King's Flat No. 2 Gravel Pump	vork, shortage water stopping work.
King's Flat No. 3 Gravel Pump	vork, rebuilding and floating pontoon.
Nozzle Pump No.	and settling dams.
Nozzle Pump No.	—
Government Ligh shops and Min (Estimated).	les power for separator, mealie mill, kshop motors.

and also repairs to

59 hours in April to
.M. 485.

ours due to flooding
ischarge 24 ft. 6 in.

urs in November for
e concentrate box.

e to silting of Feed

ood season.

H. M. WEST.

NOTE.—This table to be used for Monitors and Elevators. Service water to pumps to be included in total water used but kept separate from water delivered by Monitors.

The Institution of Mining and Metallurgy.

(*Founded 1892—Incorporated by Royal Charter 1915.*)

Bulletin No. 150.

MARCH 15TH, 1917.

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PRELIMINARY NOTICE OF ANNUAL GENERAL MEETING.

he TWENTY-SIXTH ANNUAL GENERAL MEETING he Institution of Mining and Metallurgy will be held, by kind nission, at the Rooms of the Geological Society, Burlington ise, Piccadilly, W., on THURSDAY, APRIL 19TH, 1917, at 30 o'clock p.m.

MOVEMENTS OF MEMBERS.

embers of the Institution are invited to send information in regard to their ements to the Secretary for insertion under this heading. Members visiting don are requested to register their addresses at the House of the Institution, re the Library, Writing Rooms, etc., are at their disposal.

Mr. MILTON A. ALLEN, A.R.S.M., Assoc. Inst. M.M., is now aged in the New York office of Messrs. Arthur L. Pearse & Co.

Ir. H. C. BAYLDON, M. Inst. M.M., has been appointed General ager of the Spassky Copper Properties at Atbasar and Spassky, his headquarters are now at Atbasar.

. W. DONKIN, Jr., Stud. Inst. M.M., having been discharged as after Active Service in East Africa, is now in Southern sia.

H. R. DORRINGTON, Stud. Inst. M.M., has returned to England e Republic of Colombia.

C. TAZEWELL, Assoc. Inst. M.M., has returned to England uth Africa.

I. GORDON THOMAS, Assoc. Inst. M.M., is now Assistant Manager of the Anglo-Continental Mines Co., Ltd., Nigeria.

B. TYRRELL, M. Inst. M.M., has left Toronto on a visit to

T. WARNE, Assoc. Inst. M.M., is returning to England old Coast Colony, on leave.

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the qualifications of Candidates for Admission into the Institution fulfil the requirements of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be open for inspection at the Office of the Institution for a period of at least two months from the date of the Bulletin in which their applications are announced.

The following have applied for admission since February 5th, 1917:—

To Membership—

Adam, John (*Gwalia, Western Australia*).
Haughom, Oscar (*Flekkefjord, Norway*).
Rance, Bernard (*Mogok, Upper Burma*).

To Associateship—

Daddow, Samuel (*Shamva, Southern Rhodesia*).
Wilson, Robert (*Rio Tinto, Spain*).

To Studentship—

Curnow, Thomas John (*Penzance, Cornwall*).
Dempster, Eric Richard (*Anantapur, South India*).
Pryor, Edmund James (*Wymondham, Norfolk*).
Rees, Leslie Charles (*Swansea, Glamorganshire*).
Toll, Reginald Warmington (*Bere Alston, Devonshire*).

The following have applied for Transfer:—

To Membership—

MacDonald, Donald John (*Taquah, West Africa*).
Vecelli, Cesare (*Venice, Italy*).

To Associateship—

Blandford, Stanley Charles Hooper (*Coronel, Chile*).
Bose, Aloke (*Rauchi, India*).
Warren, Richard Montable (*Cerro Muriano, Spain*).

ADDRESSES LOST.

F. B. Bradshaw, O. L. de Lissa, D. Nicholas, and J. F. Richards.

NEW MEMBERS.

'he following have been elected (subject to compliance with the ɔlitions of the By-Laws) since February 5th, 1917 :—

MEMBERSHIP—

Campbell, Edmund Ernest (*Anyox, British Columbia*).

ASSOCIATESHIP—

Bettany, Lionel George (*Shamva, Rhodesia*).
Cribb, Henry Theodore (*Venezuela, South America*).
Edmands, Herbert Richard (*Youanme, Western Australia*).
Harris, Charles Stanley (*Balaghat, India*).
Rosewarne, Richard (*Newquay, Cornwall*).
Watson, Augustus Bressan (*Broomassie, West Africa*).
Wing, Edgar Tyron (*B.E.F.*).

STUDENTSHIP—

Basto, Pedro F. Pinto (*London*).
Bernstein, Henry Leo (*London*).
Davies, Ralph Douglas Thomas (*London*).
Jones, Thomas Kirkham (*London*).
McClure, John Richard Smyth (*London*).
McKerrow, Hugh George (*Forest Gate, Essex*).

'he following have been transferred :—

MEMBERSHIP—

Heden, Ernest Charles Burgess (*Sydney, New South Wales*).
Pearse, Leonard Edward Beard (*Naraguta, Northern Nigeria*).
Price, George Blake (*London*).
Stevens, Walter Frederick (*Melbourne, Australia*).
Whitehouse, James (*Johannesburg, Transvaal*).

ASSOCIATESHIP—

Bendall, Roland (*Benoni, Transvaal*).
Dean, Arthur William Henry (*B.E.F.*).
Heywood, Jean Fernand Gaston Robert (*Johannesburg, Transvaal*).
Scott, James (*London*).
Teed, Philip Litherland (*R.N.V.R.*).
Wasse, Frank MacLeod (*Bundoran, Ireland*).
Windeatt, Thomas Reginald Amery (*Taiping, Federated Malay States*).

INDEX OF RECENT BOOKS.

NOTE.—Books marked with an asterisk are contained in the Library of the Institution.

*Abstracts of Current Decisions on Mines and Mining, January to April 1916. J. W. Thompson. Washington, D.C.: United States Bureau Mines.

*Bibliography of Australian Mineralogy. C. Anderson. Sydney: New South Wales Department of Mines, Geological Survey. 2s. 6d.

Elements of Mining. G. J. Young. London: Hill Publishing Compy. 21s.

*Geology of Graham Island, British Columbia. J. D. Mackenzie. Ottawa Canada Department of Mines, Geological Survey.

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*Method for Measuring the Viscosity of Blast-Furnace Slag at High Temperatures. A. L. Feild. Washington, D.C.: United States Bureau of Mines.

*Mineral Production of California for 1915. W. W. Bradley. San Francisco: California State Mining Bureau.

*Mineral Resources of the United States in 1915. Borax, by C. G. Yale. Clay-Working Industries, by J. Middleton. Coal, Part A: Production, by C. E. Lesher. Coal, Part B: Distribution and Consumption, by C. E. Lesher. Copper, by B. S. Butler. Magnesite, by C. G. Yale. Magnesium, by F. L. Hess. Natural Gas, by J. D. Northrop. Peat, by J. S. Turp. Stone, by G. F. Loughlin. Washington, D.C.: United States Geological Survey.

*Mines Handbook and Copper Handbook. Vol. XII. W. H. Weed. New York: Stevens Copper Handbook Compy. $10.

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*Report on Refining of Copper and Production of Metallic Zinc in Canada. Ottawa: Imperial Munitions Board.

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*Underground Wastes in Oil and Gas Fields and Methods of Prevention. W. F. McMurray and J. O. Lewis. Washington, D.C.: United States Bureau of Mines.

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-All Papers indexed may be consulted in the Library of the Institution.

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DEX OF RECENT PAPERS—*continued.*

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Selecting Abrasives for Specific Uses. R. G. Williams.—Engineering Magazine, New York, Vol. 52, January, 1917, pp. 461-8. 25*c*.

Supplies of Refractory Materials available in the South Yorkshire Coalfields. W. G. Fearnsides.—Transactions, Institution of Mining Engineers, London, Vol. 52, Part 2, 1916-17, pp. 261-79. 6*s*.

PETROLEUM.

Norfolk Oil Shales. W. Forbes-Leslie.—Journal, Institution of Petroleum Technologists, London, Vol. 3, December, 1916, pp. 3-35. 7*s*. 6*d*.

Oil Prospects in England. The Mining Magazine, London, Vol. 16, February, 1917, pp. 69-70. 1*s*.

Pyrogenesis of Hydrocarbons. E. L. Lomax, A. E. Dunstan and F. B. Thole.—Journal, Institution of Petroleum Technologists, London, Vol. 3, December, 1916, pp. 36-120. 7*s*. 6*d*.

PLANT AND POWER.

Boiler-house operation and maintenance with special reference to the Rand Power Companies' Plant. T. G. Otley and V. Pickles.—Journal, South African Institution of Engineers, Johannesburg, Vol. 15, January, 1917, pp. 90-123. 2*s*.

Historic Rock Drills. H. B. Willmott.—Canadian Mining Journal, Toronto, Vol. 38, January 15, 1917, pp. 34-9. 15*c*.

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TIN.

Bucket-Dredging for Tin in the Federated Malay States. H. D. Griffiths.—The Mining Magazine, London, Vol. 16, February, 1917, pp. 79-86. 1*s*.

Hydraulic Tin Mining in Swaziland. J. J. Garrard.—Bull. No. 149, Institution of Mining and Metallurgy, February 5, 1917.

Tin Dredging in the Federated Malay States. A. C. Perkins.—Federated Malay States Chamber of Mines Magazine, Ipoh, Perak, No. 1, December, 1916.

Wet Assay of Tin Concentrate. H. W. Hutchin.—Bull. No. 149, Institution of Mining and Metallurgy, February 5, 1917.

MILITARY SERVICE.

SUPPLEMENTARY LIST.

---

following have been notified since the issue of the last Bulletin, y 5th, 1917:

MEMBERS SERVING WITH H.M. FORCES.

H., Royal Field Artillery, (2nd Lieut.).]
C. Y., Royal Engineers, (2nd Lieut.).
, B. J., Royal Engineers, (2nd Lieut.).
L, W. E. C., Royal Engineers, (Lieut.).
P. J., Q.V. Sappers and Miners, (2nd Lieut., Indian Army Reserve Officers).
T. STONEMAN, Royal Engineers, (2nd Lieut.).
TT, HORACE, Army Service Corps, (2nd Lieut.).
I. TYRON, Royal Engineers, (Captain).

PROMOTIONS OR OTHER CHANGES.

E, C. P. L., Royal Engineers, (Captain).
. L., Royal Engineers, (Lieut.).
JOHN, Royal Engineers, (Lieut.).
, C. M., Royal Field Artillery, (Acting Captain).
IN, P. A., Royal Engineers, (Captain).
S. D., Royal Engineers, (Lieut.). *Awarded the Military Cross.*
EN, G., Royal Engineers, (Captain). *Awarded the Military Cross.*
G, B. E., Royal Engineers, (Captain).
, F., Royal Flying Corps, (Lieut.).
ES, Sir J. NORTON, D.S.O., 2nd King Edward's Horse, (Lieut.-Col.).
, S. H., XXIInd Punjabis, (Captain, Indian Army Reserve of Officers).
A. L., Royal Engineers, (Acting Captain).
. ALEC, Royal Engineers, (2nd Lieut.).
E. H. A., Royal Engineers, (2nd Lieut.).
TUART G., M.C., Royal Engineers, (Major).
LD, F. T., Royal West Kent Regiment, (Lieut.), attached to Royal gineers.
W. H., Royal Flying Corps, (Captain-Flight Commander).
P. N., Royal Engineers, (Major). *Awarded the D.S.O.*
L., Royal Garrison Artillery, (Major).
ID, F. A. D., Royal Engineers, (Lieut.).
NES, G. G., London Regiment, (Captain).
, H., Royal Engineers, (Captain).
I. B., Royal Engineers, (Lieut.). *Awarded the Military Cross.*

KILLED IN ACTION.

JAMES MCBRYDE, *Associate*, Lieut., Australian Engineers. (*In France, September 13th, 1916.*)

BERTRAM MORTON, *Associate*, Captain, Egyptian Coastguard Service. (*Died whilst on Active Service with the Western Frontier Forces.*)

WILLIAM THORNTON, *Associate*, Royal Fusiliers. (*Died of wounds in East Africa on January 3rd, 1917.*)

LIONEL CALVERT, *Associate*, Lieut., Royal Engineers. (*In France, January 30th, 1917.*)

LINDOW HEREWARD LEOFRIC HUDDART, *Associate*, Lieut., Royal Engineers. (*Died of syncope following an illness.*)

HENRY ALEXANDER DRUMMOND MALCOLM, *Student*, Royal Field Artillery. (*Died of wounds, February 16th, 1917.*)

CROWTHER & GOODMAN, LTD., Printers, 124, Fenchurch Street, London, E.C. 3.

VENTY-SIXTH SESSION, 1916-1917.

SECOND GENERAL MEETING,

Thursday, February 15th, 1917.

at the Rooms of the Geological Society, Burlington House, Piccadilly, W. 1.

MR. EDGAR TAYLOR, *President*, in the Chair.

DISCUSSION

ON

'The Wet Assay of Tin Concentrate.'

By H. W. HUTCHIN, *Member*.

'. **H. W. Hutchin** began by pointing out that on p. 17 the 'production' should read 'reduction'; on p. 25, 'zinc metal' l read 'zinc nickel'; and on p. 18 the second quotation from ger should continue to the words 'soluble in the fusion' on p. 14. the paper he had endeavoured to set out his experience in g with various kinds of products, and he only wished to give figures to emphasize the points made. He would take as an ice a consecutive set of assays on the same sample, working on he would call the old conditions, namely, the conditions before per was written.

18·1 17·5 18·38 17·75	Lime.
19·0 17·85 18·6	Pearce.
18·3	Beringer.

would be seen that the figures were not very encouraging. the paper was written, and after the experience gained,

another set of assays, but on a different sample, was taken: 16·55; 16·45; 16·45.

If one got those three results with even one method he would feel confident, but if each of those results were obtained by separate methods he would be still more confident; and the latter was the fact. The first was the Beringer method, the second the Pearce and the third the Lime. They were all worked uniformly on a large charge, acid-cleaned, and in every case the residues were re-worked and included.

He was not going to make the statement that one could not get proper assays without fractionating, but he pointed out that if an assayer got that result it should bring conviction.

Sir Thomas Kirke Rose said that as Chairman of the Tin and Tungsten Research Direction Committee, which was engaged in trying to solve the difficulties which the tin industry of Cornwall still felt in ore treatment, he was glad to have the opportunity of thanking the author for the very excellent paper now before them. The paper had been accepted by the Committee as a part of the researches in which they were engaged and was useful in facilitating their work. He regretted that he had only had time as yet for a hurried look through the paper, so that he was unable to discuss it in detail, but he saw enough to realize that it was of great value.

In his laboratory they had to make a certain number of tin assays, and although they were not working on cassiterite but on alloys, nevertheless they highly valued the contributions which workers in Cornwall and others had made before the Institution from time to time, because the conclusions arrived at in assaying tin concentrate were in many cases extremely useful to them.

As an assayer, he was glad to observe that while the representatives of the allied professions were thinking and talking about things, the assayer continued to do things. At present they were considering what could be done to improve the extraction of tin in Cornwall, and while they were thinking about the fringe of the subject, the assayers in the course of the last few years had gone far to solve their particular problem. He congratulated the author on the results of his work.

Mr. C. O. Bannister said he had read the paper with pleasure, more especially perhaps because it offered good confirmation of at least two points on which he had been keen for some time: the first was the possibility of the contamination of samples during the crushing in the laboratory, and the second was the unreliability of nickel as a reducing agent for tin in solutions.

With regard to the question of the possible contamination of

samples during the grinding, this was a very important question, but fortunately was one which was thoroughly understood in the best laboratories, where suitable precautions were taken to eliminate the evil effects of the contamination. In some of their teaching institutions he was afraid the matter did not receive the serious attention it deserved, because one had frequently seen lusty young students grinding away on the bucking board looking as though they were intent not only on producing finely divided samples but also buyers' assays.

The author gave a certain amount of information, together with some experimental evidence on the effect of grinding, but he was afraid that he had not given them all they desired in this connection. On many points where further details were desirable they were found lacking. For example, on p. 6 the author described some experiments on the crushing of material in iron mortars, and gave the results of an attempt at estimating the iron in the product by contact with a solution of copper sulphate. The attempt was unsuccessful, probably because the steel of which the mortar was made was unsuitable for reaction with copper solution. Further on the author gave the amount of iron he found by a gravimetric determination, and then he ran a blank test, the result of which was given as 'very little.' There were very different ideas as to what that might mean in such a case, and it would be desirable to have a definite figure.

In the next place the author gave the log of the weights of Wedgwood pestles which were used during the grinding of the samples, and that log of weights was very interesting and convincing to a certain point. Without a more definite statement as to the approximate weight of the samples crushed, however, no clear deduction could be made from the details given. In the case of Pestle B, for instance, if they assumed the samples weighed about 20 grm., they found that in losing 11 grm. during the crushing of 240 samples of tin and wolfram concentrates it would account for a dilution of only 0·25 % and in losing 1 grm. for 50 wolfram samples it would account for a dilution of 0·1 %. In the case of Pestle C, this in losing 8 grm. for 80 samples of tin concentrates would account for a dilution of 1·18 %. In addition to these amounts there would be smaller amounts lost by the mortar.

On p. 8 there was a description of some experiments on the use of the muller and slab for the crushing of tin concentrate. The author states that the muller and slab were cleaned with several lots of concentrate; then he described some experiments in which three lots of concentrate were crushed down in two stages, giving samples

numbered I and II; I A and II A; I B and II B; in order to get any interpretation of value from the results obtained the amount of tin in each of the six products should have been given. Instead of that the author stated that samples I A and I B were not assayed for tin. After reading very carefully one wished very much that those tins had been determined, so that the effect of grinding in the two stages of fineness on the muller and slab could be ascertained. Furthermore, samples I and II gave lower results than II A and II B, and the author assumed that the plate was not clean, though he expressly stated that it had been cleaned with several lots of concentrate.

The author had done good service in drawing attention once more to the possible dilution of samples during crushing, but as nothing very definite had been given as to the effect of work done on the muller and slab and the amount of dilution to be expected from crushing samples, the speaker had carried out a few experiments with a sample of fairly pure hard quartz. He had prepared a sample which was +30 — 10, and then commencing in each case with 80 grm. of the sample, he crushed it on a plate to pass a 30, a 60, and a 90 mesh sieve. Then in a similar manner, with three new portions, he used an iron mortar to crush through a 30, a 60 and a 90 mesh sieve, and determined the iron in each one.

The following results were obtained:

		After magnet.
Original Sample	0·15% Fe.	0·15
Ground on Plate to pass 30	0·87	0·17
Ground on Plate to pass 60	1·95	0·17
Ground on Plate to pass 90	3·07	0·25
Ground in Iron Mortar to pass 30	0·70	0·18
Ground in Iron Mortar to pass 60	1·17	0·15
Ground in Iron Mortar to pass 90	1·65	0·17

These figures showed that very serious contamination could occur on a muller and slab. One got up to even 3% of iron quite easily. These results also indicated that the plate was very much worse than the iron mortar with regard to the contaminating effect.

In the case of non-magnetic materials it was a very simple matter to remedy this dilution by putting a magnet through the crushed material, thus getting out the iron taken up from the crusher.

To illustrate this, he had passed a magnet through each of the crushed portions, and again determined the amount of iron present. Only in one case had he got a figure for iron more than 0·02% higher than that obtained with the original quartz. These results show that, so far as non-magnetic materials were concerned, they could eliminate the error by the use of a magnet quite simply.

In this connection it was as well to remember that where one had

non-magnetic materials, in which magnetic separation could be used, it was better to use a crusher made of relatively soft iron or steel rather than a specially hard steel such as manganese steel, because manganese steels and most of the special steels which would contaminate the sample less were non-magnetic, and one therefore could not use the magnet for the separation of the particles from the sample.

In the next place a question arose as to what should be done when magnetic or partially magnetic materials had to be dealt with. The simplest method of dealing with these was to crush a portion either in an iron mortar or on an iron plate, and another portion in a Wedgwood mortar or a mortar of similar material, and then determine the amount of iron in each. By taking the amount of iron found in the sample crushed in the Wedgwood mortar as the iron natural to the sample itself, and deducting it from the iron found in the other samples, the amount of iron taken up could be ascertained and allowed for.

He would like to refer to a paper also referred to by the author, namely that by Mr. Eastaugh on 'The Effect of Different Methods of Crushing on the Ash of Coke,' read before the Institution in May, 1915.* That paper made matters appear really serious, because it showed that the amount of ash in coke might be returned over 3 % too high owing to the contamination of the sample during the grinding.

Also, he would like to say that coke was generally sufficiently magnetic to prevent the use of magnetic separation after crushing it in an iron mortar.

To illustrate the point he had crushed a good sample of hard furnace coke under conditions similar to those in the experiment with quartz.

The following were the results :

	Ash %.	Fe_2O_3 %.	Ash less Fe_2O_3 due to be taken up.	
Ground on Plate .. to pass 30 mesh sieve	6·81	3·82	6·16	Mean 6·28.
" " .. " 60 "	7·81	4·64	6·34	
" " .. " 90 "	8·78	5·64	6·31	
" in Iron Mortar " 30 "	6·98	3·85	6·30	
" " " " 60 "	7·12	4·10	6·19	
" " " " 90 "	7·90	4·71	6·36	
" in Wedgwood Mortar " 30 "	6·38	3·07		Mean 3·17.
" " " " 60 "	6·43	3·25		
" " " " 90 "	6·66	3·18		

* *Trans.* vol. xxiv, pp. 483-5.

The first series of ash determinations was not very encouraging, although the sample was very carefully selected, and a size +30−10 taken to commence with, but on making the correction as already indicated, quite passable results were obtained.

He would like to mention that the effect of the contamination in the two cases, tin ore and coke, was very different. For example, in the case of tin ore the iron acted merely as a diluent, whereas in the determination of ash in a sample of coke contaminated with iron they not only weighed up the whole of the iron they had contaminated the coke with, but during the determination of the ash they had oxidized it to ferric oxide from the metallic state, increasing its effect by 43 %.

Suppose one took a sample of tin ore containing 10 % of tin and a sample of coke containing 10 % of ash, and crushed both under such conditions as to get 1 % of metallic iron contaminating the samples, what result would it have on the final figures? In the case of the tin ore, instead of 10 % of tin we should get 9·901 %, whereas in the case of the coke we should get 11·329 % instead of 10 % of ash. So that while the contamination of 1 % of iron would only make a difference of 0·1 % of tin on a 10 % tin ore, it would make a difference of 1·3 % of ash in a coke containing 10 %.

Turning to the question of the determination of tin, he himself had a preference for the Pearce method. In laboratories where a large number of different samples of different origin were turning up he thought there was a great deal to be said for a method in which the whole of the material weighed up was obtained in solution. At the same time he must confess that in laboratories where a large number of similar samples were constantly being treated there was something to be said for the Lime and the Beringer methods in which total solution was not obtained.

With regard to the reduction of the tin solution by nickel, in the discussion* on Messrs. Wraight and Teed's paper he had pointed out that there was a tendency for nickel to appear to be in a passive condition, in which case it did not act as an efficient reducer. This was a serious objection to nickel and one not shared by iron.

There was evidence in the present paper that the author had also found this to be the case, and he had also given the results of a number of experiments using as a reducer metallic nickel of different origins. The results obtained were very interesting, and it would have been well if the author had devoted more attention to the behaviour of nickels of different origin, and ascertained why there was a difference in the results obtained.

* *Trans.* vol. xxiii, p. 336.

Of course the use of zinc as a reducer of tin and also as a precipitator of tin was very well known; it was largely used before the present methods of assay were perfected. From the figures given by the author, in the various tables, there would seem to be no special advantage in the use of zinc nickel over nickel except in the presence of certain impurities such as titanium. He thought that one of the great advantages of using zinc nickel would prove to be the saving of time, which was an important matter but one on which the author had given no information.

He would like to add that after comparing the author's figures obtained in the nickel period and in the zinc-nickel period he had come to the conclusion that the higher results reported in the zinc-nickel period were probably due to greater care in the crushing of the samples in the first place and not to the use of zinc nickel, because, as he had already said, there was very little evidence in the paper that zinc nickel was better. There was one table to which he would call particular attention, namely the table on p. 20; it would be difficult from the figures shown there to decide which were the better or even the higher results, as in only one case was there a difference of 0·1 %, and that could be considered as within experimental error.

He thought the paper would increase the interest taken in the methods of determining tin and considered that a new research was desirable in which pure solutions were used, in spite of the objections of many assayers to work with anything but minerals in an investigation of this kind.

Mr. H. K. Picard looked upon the paper as a valuable addition to the literature on the subject of tin assaying and was sure that all workers in that line would be grateful to the author for the trouble he had taken in carrying out and publishing his researches. The author's labours, with those of other recent investigators, had now removed any justification for the charge, which until recently had been levelled against assayers, that no satisfactory method for the assay of tin ores had been devised. Chemists as a rule had not the time or opportunity to investigate these methods in close detail for themselves, and were, therefore, obliged to rely largely on the literature of the subject.

He was looking forward to reading the author's promised communication upon the assay of low-grade residues and ores, because, good as he thought the tin assay now was, it certainly had limitations when applied to material of from 5 lb. to 10 lb. of tin per ton.

The author dealt mainly with low-grade concentrates, stating

that difficulties were encountered in the assay of that class of material; and, further, that those difficulties were now removed.

He (the speaker) was somewhat disturbed to find that according to the author there was difficulty in assaying ores of the character referred to. He had had occasion recently to deal with a number of parcels of ore of approximately the same value as the author discussed, and might mention certain figures obtained. He had considered the last 24 parcels disposed of, without making any selection or omitting any of them, and would add that in no case was a reference necessary. The average assay of the 24 lots obtained by the seller was 25·98 % of tin, whilst that of the buyer showed a slightly higher figure, namely 26·04 %; this he thought showed very satisfactory general agreement. Further, where the seller was higher than the buyer the average excess was 0·45 %; and where the buyer was higher than the seller the average excess was 0·48 %. These results, commercially speaking, satisfied both parties; such differences as persisted he thought were due more to sampling errors than to discrepancies in method of assay. The author would probably reply that both buyer and seller were low; he might say he was the assayer on the one side, using the Pearce method, but did not know the method used by the other side.

There were a few points in the paper to which he wished to refer. It was gratifying to read that, though difficulties were alleged to exist, these would be successfully met if they followed the method set forth by the author; but, accepting this, it was unsatisfactory to read, a little later on, that 'by no procedure within the author's experience can any but low assays be returned on certain rough samples, viz., alluvial tin concentrate, jig samples of tin and tin-wolfram concentrate.' This means that even were the author's advice carefully followed, they were still not free from uncertainty.

Mr. Bannister had referred at length to the question of grinding, and had put some convincing figures before them. He agreed with much that Mr. Bannister had said, but did not know how they were going to surmount this difficulty. It was a counsel of perfection to advise the grinding of all samples in an agate mortar, but he considered this would not be capable of adoption in general practice. Referring to the test in which the author found 1·6 % of iron soluble in HCl, this quantity by calculation would bring the tin contents down to 73·89 %, when compared with 74 % actually found, which was a remarkably close agreement. But he would point out that, though the ore *before* grinding had been treated with hydrochloric acid, it was likely that, if the first treatment had eliminated iron, some additional soluble iron compound might be liberated from

the ore on finer grinding, and that the whole of the 1·6 % of iron was not necessarily due to metal derived from the grinding plant. With regard to the Wedgwood tests, the log of the weights was interesting, but would gain additional value if the weights of the samples ground were given.

As to the samples mentioned on the top of p. 9, he went, perhaps, rather further than Mr. Bannister, and took the view that the differences in assay might well be due to the uncertainty of correctly sampling material so coarse as 20 mesh, and that it might well have been impossible to prepare three samples of precisely equal value to start with. So far as the record went it showed that grinding on the plate yielded a higher instead of lower result: the author's explanation of this curious inconsistency, that the grinding plate could not have been sufficiently cleaned, was hardly satisfying to him; with such a careful manipulator as the author this amounted to begging the whole question.

The author next counselled them to acid-clean their samples, particularly if ignorant of their character, as by so doing they would know nothing of interferences; yet in spite of this, the author shows that some concentrates gave lower results after acid-cleaning than did untreated material; thus interferences apparently still existed.

He did not propose to refer in detail to the interesting tables given as to samples containing added impurities. It would be impossible to criticize these effectively unless one had had an opportunity for checking the results; he therefore accepted the figures without question. He would only say that on p. 17, Series B, there was a remarkable agreement in all the results given where the zinc-nickel reduction was employed; unless one knew the author's great skill, one might be tempted to quote Mr. Beringer's remark that 'exceptionally concordant results were unconvincing.'

He was glad to see that the author gave a recommendation as to how the iodine should be run in. He believed some assayers held the view that if all were run in at once, as recommended by the author, one ran the risk of oxidizing substances other than tin which might be present; perhaps the author would elaborate this point.

With regard to the last two pages of the paper, Mr. Bannister had dealt with the figures at the top of p. 25; but the speaker noticed that if they included the 20·3 % assay of parcel '2' they would get an average of 19·8 %. Strictly speaking, all three assays ought to have been averaged, and they were not justified in assuming that 20·3 % was any more likely to be correct than 19·7 or 19·4. Presumably the two latter were obtained by ordinary nickel reduction, and as, in the

absence of interfering substances, the author had shown in several of his tables that plain nickel gave as good a result as zinc nickel, the speaker's opinion was that the differences shown were quite as likely to be due to sampling error.

The list of 78 assays of samples sold certainly bore out the author's contention that he got a higher result by zinc-nickel reduction; but he was not equally certain that the author had proved that the use of zinc nickel was the cause of the higher result; nor, which was of greater importance, that it was necessarily the correct result. On examination of the figures it would be found that the buyer's average assay of the whole lot was 18·96 % and the reference assay 19·6 %. The difference between buyer and seller (taking the latter at 20 %) was unduly large; but as between seller and reference (20 % and 19·6 %) the difference might well be accounted for by slight discrepancies in samples; to his mind it did not prove that in giving the higher result the zinc-nickel method was necessarily more correct than the plain nickel.

Mr. W. H. Trewartha-James said the paper, practically speaking, could only be discussed by assayers in professional practice; but it was also interesting from other points of view, to which he might refer.

This paper was published by the Institution of Mining and Metallurgy as one of its Cornish Tin Research papers, and he thought they were all quite pleased with the standard which the author had maintained; they might congratulate him and the Institution on the timely presentation of an important contribution of that character. The author had embodied in it the work almost of a lifetime, and the paper was full of valuable practical directions.

Mr. Bannister had already referred to the very interesting way in which the author had developed the question of the dilution produced, when grinding samples, by the abrasion of the grinding medium, due to the hardness of the cassiterite, and the relative softness of the pestles and mortars which were in general use. He did not know if professional assayers would admit that they were not fully aware of the extent of this source of error, as claimed by the author, but it called for serious attention, and apparently the only remedy is to prepare all cassiterite samples by grinding with an agate mortar and pestle.

On p. 7 the author stated that the differences shown in the table were clearly due to the method of grinding, and not to differences in the methods of assay. He did not agree with that. The differences in the table were so inconsistent and variable in themselves that it was unlikely that they were due solely to

lilution; more likely they were due in part at least to
l assay errors.

[they got 67·25 % by the Lime method unpowdered,
y the Beringer method powdered. It was difficult to
he data put forward a variation of 2·45 % was caused
ing of one sample, whilst in two similar cases the
s within 0·4 %.

p. 8, the author stated 'with regard to pestle C, its
ebruary 26th, 1914, was 445 grm., and by May 19th,
ght had decreased to 437 grm.; in this period it was
r tin concentrate, and the approximate number of
30.' Presumably those 8 grm. of material entered
ple. He asked the author if it would be fair to assume
rized about 10 grm. each time.

W. Hutchin said the lost weight of the pestle would
ubled, to allow for the abrasion of the mortar.

wartha-James thought it would not necessarily be
e mortar loss might be much less.

W. Hutchin said he had given his opinion that the
as in fine grinding. If a smelter wanted to grind he
n; fine grinding was done on a small quantity only.

wartha-James continuing said that assuming the
nt finely ground was 10 grm., and the average content
t. tin, then the actual dilution due to the loss by the
worked out at 1·82 % in that particular case. If, how-
sumed the average tin content to be 20 % on the same
rence would be only 0·52 %. If they knew also the
ortar, there would be still greater dilution, but he did
would be equal to the pestle loss. Again, taking the
r of samples on p. 7, where 240 samples were prepared
when the difference in weight worked out at 13 grm.,
me factor, average amount ground fine, equal 10 grm.,
erence due to dilution from the pestle alone was only

was that he did not think one could accurately determine
e by mere comparison of assays. The only way to
e actual dilution, in his opinion, was by carefully
pestle and mortar over a long series, and carefully
e quantities ground fine, and the metallic contents.
robably held the same view or he would not have kept
ortunately his data was not complete.

r had certainly given sound advice when he recom-
se of the agate pestle and mortar for preparing tin ore

samples. That should be compulsory. If he were to make an agreement to-morrow for the purchase and sale of tin ore he should specify how the sample was to be prepared, how the moisture should be ascertained, and the method by which it was to be assayed, as was done in all ore-contracts in Canada and America.

With regard to arbitration assays and the splitting limits, it was understood the usual splitting limit was 1 %, which showed clearly enough that the trade was satisfied with a concordance, under or over, of 0·5 %. Would the author state what was the splitting limit for the 73 reference assays on p. 26.

Mr. H. W. Hutchin said it was 1 %.

Mr. Trewartha-James said that showed what the position was. The question of disagreement between buyers and sellers' assays and reference assays, and the practice of splitting limits, was not strictly a question of pure assaying at all, nor evidence of correct methods or accurate practice, and he was not sure that the paper would not be very much improved for publication if that part of it were omitted. The differences between sellers and buyers' assayers ought not to be quoted as evidence on the question of accurate assaying.

The paper showed that a great deal of importance was attached to the assay of low-grade concentrate. Most of the Cornish high-grade concentrate was still sold by the ticketing system. This required no comparison of assays, no reference, no splitting limit, but the price obtained by that system was subject to unexplained variations. The sale of concentrate by agreement based on assay value and market price of tin was gaining ground and gave a true and proper method of buying and selling tin ores and concentrate.

It was interesting to note that the market for low-grade concentrate was rapidly extending. He believed that was due to improved processes coming into use, hence the author had rightly devoted very special attention to the correct assay of a concentrate containing 15 % to 30 % met. tin.

He would look forward with very great interest to the further paper which the author had promised on the assay of low-grade material containing from 0·5 % to 2·5 % met. tin, because he entirely agreed with Mr. Picard that whilst they were pleased to hear that the higher-grade materials could now be assayed with reasonable concordance, they still knew that with lower-grade material, and particularly with 4 lb. to 10 lb. tailings, they got large variations which have not yet been fully explained.

He desired to repeat his high appreciation of the author's work on this special subject.

Mr. Sydney W. Smith said that he had read the paper with a great deal of interest. He had also re-read the author's previous paper, published in 1914,* and also some considerable portions of that memorable discussion which followed, a discussion which he thought occupied 76 pages of the *Transactions* of the Institution. It seemed to him that the present contribution formed an admirable supplement to the previous one, and also to the paper of Messrs. Wraight and Teed which was presented at the same time and which was discussed conjointly with Mr. Hutchin's paper.

At the same time, he felt that a mere acquaintance with the literature of the subject did not entitle him to offer any sort of criticism, because his experience of the tin assay was confined almost entirely to tin alloys. His experience, therefore, began at a stage where, if he interpreted the literature correctly, most of the difficulties in assaying tin ores and concentrates should really have come to an end; that was to say, a stage where comparatively pure tin solutions merely required reduction and titration. Even at that stage, however, one was struck by the number of possible variants which were presented. Those that occurred to him were, for instance, the acid strength of the solution, the volume of the solution, the particular reducing agent which was to be used, and, if one used nickel, what particular brand or kind of nickel would be most suitable. Then again, there was the method by which the solution should be cooled so as to avoid oxidation, and the particular strength of iodine which should be used in titration. There was also a question of the proportion of potassium iodide in which the iodine should be dissolved, and the particular character and amount of the starch most suitable as an indicator. Those were all factors which might have an influence on the result. The fact that the tin assay presented so many possible sources of variation in procedure, accounted perhaps for the voluminous literature on the subject.

But there was also another feature which was perhaps largely responsible for a great deal of the trouble which had arisen in connection with that assay, and that was the very desirable end, which was always kept in view, of bringing a chemical determination, perfectly accurate in itself, within the limits of what was usually regarded as an 'assay,' namely, something which was rapid, sufficiently accurate, and which admitted of the minimum remuneration. One constantly found in the paper, and also in other papers, advice with regard to taking precautions, which tended to make that shortening of the process to which he had referred more and more difficult.

* *Trans.* vol. xxiii, pp. 269-79.

For instance, on p. 22, the author said, 'As a matter of prudence it would be better to remove other than small quantities.' That sort of recommendation, as a matter of prudence, cropped up continually in works dealing with the assay of tin ores or concentrates. It rendered the task of one who wanted to turn out a number of assays quickly, very difficult. The whole question of procedure, therefore, seemed to depend on being able to find quickly and exactly to what extent time-consuming operations might be either omitted altogether or shortened. Anyone, of the author's experience, familiar with all the usual difficulties, had only to consider the unusual and exceptional difficulties. It was quite clear that the author would arrive at some suitable method much more quickly than a person with less experience dealing with an ore with which he was not familiar.

With regard to the use of nickel, Mr. Bannister had pointed out that several brands of nickel had been considered, that they had been considered under names indicating their origin, and that some doubt existed as to their applicability. Mr. Bannister would go the whole length and abolish the use of nickel altogether. The author's position was almost similar, because he advocated partial reduction by zinc, finishing off with nickel. They appeared to be in agreement as to certain objections to nickel.

He thought that the method of referring to nickel provided by various firms should be modified so that they might really know something about the nickel. He thought some definite idea should be obtained as to its purity. Presumably there were impurities present in the brands used, and perhaps one benefit which they might obtain after the war would be a Bureau of Standards, where brands of pure metals might be verified, so that they might not have to rely on any of the dealers, however reputable, for their standards. That was a matter which ought not to present very great difficulties.

He thought the author's statement at the bottom of p. 27 was fully justified, that: 'There are good reasons for the hopeful statement that workers with a knowledge of the imperfections and weaknesses of the assays based on the iodine titration will, if that knowledge is applied, return assays in agreement even when different methods are pursued.'

Mr. E. A. Wraight said that for certain reasons his remarks must be taken as strictly unofficial. He had really only attended as a listener. He was glad that the President had not called upon him till the last moment, because practically everything that he *could have said* had been said much more effectively by other

speakers, especially by Mr. Bannister, who had cut the ground from under his feet in an admirable manner.

He really could not understand the great prejudice which assayers seemed to have against nickel. He had always regarded nickel as being far and away the best reducing re-agent to use, and one which gave an extremely clean solution.

The members would remember the paper by Mr. Teed and himself which had been presented about three years ago. They had conducted about 300 assays, and in every one they had used nickel as the reducing agent. He did not know what Mr. Bannister's or the author's methods were exactly, but he would state what Mr. Teed and he had done with their nickel, and they had no trouble at all. First of all they cut the metal into several strips. Directly the assay was over they poured the solution from the flask and placed the nickel in a beaker of water. When wanted again, there was that nickel, to all intents and purposes the same nickel as in the previous assay, and they used it over and over again without experiencing the slightest difficulty. They never found the metal assuming the passive state. If he ever returned to professional assaying again, he would certainly return to nickel.

The effect of grinding and crushing had been frequently mentioned in the course of the very interesting discussion. He thought one point had been overlooked by everybody. They were all seeking for the causes of dilution, and spoke of Wedgwood mortars, bucking boards, and so on, but one important fact seemed to have been missed, namely, the effect of 'dusting.' He considered the effect of dusting far more important than any dilution which might be introduced through grinding and crushing. If one took 5 grm. of any sample and ground it in any sort of mortar he would guarantee that unless the mortar was of a particularly soft description they would certainly not get 5 grm. of a crushed sample out again; they would get appreciably less.

That was going to form the subject of a contribution at a subsequent date: at least that had been his intention; but he did not know when he should have an opportunity of again indulging in professional work, and therefore was going to give that information to the members for the benefit of those who had time to go into the subject, i.e. the effect of dusting. Although nothing to do with tin, he could give rather a forcible example in the case of copper. He once had 15 tons of copper ore to experiment upon, in order to determine the effects of jigging, crushing, screening, etc. That copper ore was not unknown to their President. He

had had to weigh most carefully every product from every operation. The copper ore was a rich one, running about 15 % in the first instance, and 1 ton of it, after weighing all the products of the various operations, yielded something like 18¾ cwt. That meant that there was 1¼ cwt. lost in grinding and screening.

It might be said that the analogy was rather far-fetched between grinding on a big scale and crushing in a mortar, but perhaps it was not so far-fetched if one likened it to crushing in an iron mortar or on a bucking board. In the case of coke, dusting did not matter; presumably the product which passed away was all of the same chemical composition, but when one was crushing an ore which consisted of several different components, the effect of dusting could not be lightly disregarded.

The particular copper ore mentioned gave about 15 % in the crude state as received from the mine, or, at any rate, as he received it; he did not know what preliminary treatment or dressing had been effected before he got it. After clearing the workshop and collecting every fragment they could off the shafting and belting, and so on, though he certainly did not succeed in collecting the full amount he had lost, he recovered quite a considerable proportion of it. He found that the copper percentage was raised to about 23 % in the dust, the reason being that the copper pyrites present was much more friable and more easily disseminated than the gangue of the ore.

He would give another example, which was even more striking. The Falcon ore ran about 2·3 % of copper, or it had done so when the mine was first opened up. The lower levels contained considerably richer material. He had had a large parcel of the surface ore, and was conducting an exactly similar series of experiments as in the case previously mentioned. The figures he obtained were even more remarkable. The copper portion of the Falcon ore was very friable indeed, and formed one of the most difficult problems to solve in the treatment of the ore. He collected the dust after the experiments were over, and to the best of his recollection, the work being done several years ago, the dust from that copper ore assayed somewhere about 11 %. He thought those figures were quite sufficient to show that the effect of dusting was very considerable, and certainly could not be lightly passed over. He thought the figures which Mr. Bannister had shown with regard to iron in the samples which had been ground on the plate and in the iron mortar might be partly explained by dusting. There was a free current of air on a bucking board which might waft away a considerable proportion of the ore. On the

other hand an iron mortar was comparatively enclosed, and one was not likely to get such a big loss as with the iron plate.

He hoped that if any future work was done on the effects of grinding and crushing those points would be taken into consideration. It might be found they had quite a considerable bearing on the dilution or enrichment of samples.

Mr. H. W. Hutchin, in reply, said that the reference assays were rather delicate ground. The sellers' assays were taken from his record book; not from the exchanges. As far as the reference assays were concerned, they were taken from the reference certificates. The buyers' were as they were received in the exchanges. So that the sellers' and the reference assays were actual assays.

He proposed to give his reply later on in writing, but there was one other point he might mention. It was not to be assumed that he hopelessly condemned nickel as a reducing agent. He stated clearly and distinctly that there were lapses. Taking his professional experience, he put the question of relying absolutely and solely on the completeness of the reduction of nickel behind him. If he were compelled to work with nickel he would be quite satisfied to use it, but he would use titration after titration: he would have to take steps to meet the situation.

He wished to make a little explanation. His laboratory was a works laboratory, and the paper was the result of work done in his odd moments, and was not a continuous piece of work. It must be criticized in that light.

Mr. W. H. Trewartha-James expressed the hope that figures might be given later on the effect of 'dusting,' in preparing samples of various minerals. Would the effect caused by dusting counterbalance the effect produced by the abrasion of the pestle and mortar?

CONTRIBUTED REMARKS.

Mr. R. C. Griffith: I should like to congratulate the author on the courage shown in producing his second paper on this subject. It is one that has provoked much discussion in the past, and will still do so in the future, especially now that more complex ores are being treated. I wish to make the following comments and friendly criticisms.

The question of contamination by crushing is an important one. As this is an operation usually performed by a junior, who often

lacks knowledge of the dangers incurred, it is well that the author has called attention to it.

On p. 10 the author states: 'The substitution of nickel for iron as a reducing agent was an improvement, and has met with general acceptance.' I am afraid I must take exception to this statement.

In our laboratory the Pearce method is frequently used, and our experience of nickel reduction has been very unsatisfactory. We consider this to have been largely due to variations in the purity of the nickel, and it was because of this inconsistency in the action of this metal when used for tin reduction that we gave up using the same, and have for some time past used pure soft iron, the quality of which is not nearly so variable.

When obtaining a fresh stock of iron, we always test it by means of a blank experiment, which is carried out under similar conditions to an assay, and reject it if more than 0·10 cc. of iodine is consumed (iodine strength 100 cc. = 1 grm. tin). Iron passing such a test has, in our experience, been quite satisfactory for use in tin reduction.

Many blank experiments were carried out with various brands of nickel, and consumed much more than this, and perhaps may be one of the causes why the author has obtained such varying results when using nickel from different sources.

Similarly, blank trials with ferrum redactum consumed much iodine; for this and other reasons it was not considered suitable for use.

I should like to emphasize the point, that when reducing with iron, I consider a period of 20–25 minutes from the time of decolorizing (i.e. the ferric iron has been reduced to ferrous) is quite sufficient, provided also that the reduction is very brisk; a sluggish reduction invariably produces low results.

My experience of the effect of copper when iron is used for reducing is somewhat different from the author's, and is shown in the series of results tabulated below, made by my head chemist, Mr. C. E. Barrs:

	Copper present (about 9 %).	Copper removed.
1	21·25 %	21·06 %
2	18·58 %	18·31 %
3	21·28 %	20·96 %
4	17·16 %	·16·87 %
5	20·32 %	20·03 %
6	18·27 %	18·16 %
7	16·67 %	16·31 %
8	20·74 %	20·50 %

In conclusion, I shall look forward with pleasure to further communications on the wet assay of low-grade ore and tailings, as the many discrepancies which may arise in this material can easily lead to serious errors.

Mr. William Kitto: The reception of Mr. Hutchin's paper at the meeting of the Institution was to me somewhat disappointing, as it included more than one novel point; but I have little doubt that the reason was at any rate partly due to the fact that the majority present had been unaware of the zinc-nickel reduction for tin concentrates as compared with the nickel reduction, and had not had time to make a fair comparison of the two methods.

In conversation with the author about a year ago, he suggested the use of zinc dust to me for a trial and opinion, and after a short series of comparative assays by both nickel and zinc-nickel reduction the advantages of the latter method was soon apparent. Not only was the reduction period reduced from 1 or 1¼ hours to about 15 minutes, but I found better agreement in duplicate assays, the incomplete reduction sometimes experienced with nickel being eliminated. I see no reason why zinc dust should not be used in conjunction with iron instead of nickel as a reducing agent, but have not had time for experiment with this combination.

The author, perhaps, did not make the advantages claimed for the use of zinc sufficiently clear. I have had this modified method of reduction, in conjunction with the Pearce method of fusing the assay, in use for a considerable time on concentrates, during which time hundreds of assays have been made, and I am of opinion that the majority who use nickel at any rate will, after a fair trial, adopt the use of zinc dust as well for solutions rich in tin.

Another most important point in the paper is the question of acid cleaning. This procedure I have never abandoned during nineteen years for any of the different methods in use from time to time, viz., the old Cornish assay, the cyanide method, hydrogen reduction, Beringer process, Pearce or Lime methods, except in the case of clean cassiterite when the procedure is unnecessary; and my experience during later years with many pyritic and other rank concentrates, including many of the Cornish ones referred to in the paper, shows more than ever the necessity of continuing this step, notwithstanding what has been written to the contrary. The skipping of this procedure has often taken place, I am afraid, in laboratories since Messrs. Wraight & Teed demonstrated that arsenic did not interfere in the Pearce assay under certain specified conditions, which was based on the well-known fact that it can be distilled off from a solution of tin and arsenic chlorides. In the case of some

Interference from other Salts also in Solution.—While the Beringer and Hutchin methods have the possibility of objection on the grounds that the whole of the tin may not be in solution, the Pearce method on the other hand is subject to the criticism that since everything originally in the material to be assayed is in solution, conditions favourable for the maximum interference of salts undoubtedly exist.

Such, briefly, are the main outlines of the subject of tin assaying as it exists to-day. Were more detailed consideration indulged in, much could be said on such questions as:

The acidity of the Solution.—We ourselves found after careful experiment * that with increasing acidity a decreasing interference arose from the presence of arsenic (a fact not confirmed by Mr. Hutchin), but on the other hand, increased interference from titanium salts was found to take place, the latter difficulty being got over by means of an original fusion with potassium hydrogen sulphate.

Iron Reduction.—Both Mr. Hutchin and we ourselves † regard reduction with 'ferrum redactum' as a sure way of introducing errors in the determination of tin in tailings and low-grade ores, but on the other hand Mr. Picard ‡ advocates its use.

Copper.—Both Mr. Hutchin and we find that copper in considerable quantities causes an interference that requires special treatment. Here, perhaps, I may be permitted to join issue with Mr. Hutchin. He, it would appear, mildly reproaches us for failing to definitely state how great a percentage of copper must be present before special methods are employed. Would it not be as just to reproach a zoologist for failing to state at what agé a kitten becomes a cat?

Though the assay of tin in ores and concentrates has improved and is improving largely as a result of such works as those of the late Mr. J. J. Beringer and Mr. Hutchin, it is not yet entirely satisfactory—a fact clearly proved by sending a sample of the same material (say a dirty Nigerian concentrate) to several different assayers of the highest repute. Therefore, it is suggested that the Institution, at the termination of the War, appoint a Committee to investigate and report on methods for the determination of tin in ores and concentrates. Such a committee was asked for nearly fourteen years ago by Mr. J. F. C. Abelspies,§ and its usefulness would be even greater now than then. By giving an authoritative

* *Trans.*, vol. xxiii, p. 368.
† *Trans.*, vol. xxiii, p. 372.
‡ *Trans.*, vol. xxii, p. 275.
§ *Trans.*, vol. xiii, p. 100.

opinion on this important question, the Institution would make a notable and valuable contribution to the general improvement in technical methods, a contribution which would be of the greatest help and usefulness to the tin producers of the world, who happily are almost entirely located within the Empire.

The President said with regard to the most interesting and valuable paper,

'Hydraulic Tin Mining in Swaziland,'

by J. Jervis Garrard, *Member*,

there was unfortunately no time to introduce it, but it would be discussed by correspondence.

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CONTRIBUTED REMARKS

ON

The Economic Geology of the Insizwa Range.'

By W. H. GOODCHILD, *Member.*

)r. A. L. du Toit: It is a pleasure to find that the main clusions of the geological survey have been confirmed by Mr. ›dchild in his extremely well-reasoned paper, a contribution ch will be much appreciated by geologists in South Africa.

t was only through the work carried out subsequently over the ›ining region that definite evidence was forthcoming bearing n the nature of the concealed base of the Insizwa mass.

he pressure caused by topographical and geological fieldwork ented the fuller working out of the many problems that pre- ;ed themselves; moreover, Mr. Goodchild had the advantage eeing a later stage of development and of obtaining data which as either refused or requested to consider as confidential.

'n one point I have to dissent entirely from the author's con- ›ion, namely, the physical state of the sediments at the time heir intrusion. The strata at Insizwa and Tabankulu are of nian age, and the horizons, which once overlay the region and ch are fully developed some miles to the westward, comprise whole of the Triassic, between 3500 and 4000 ft. in thickness, an unknown amount of Rhætic basalts (belonging to the mberg series) The Karroo dolerites, of which the gabbros and tes form merely a local phase, were injected at the close of the lt outpourings and are most probably of very early Jurassic age. younger vertical dolerite dykes can only be slightly later in age, in some instances they acted as feeders to the sheets injected in higher strata.

'here was sufficient time consequently to allow of the consolida- of the sediments in question (prior to their intrusion) into a lition approaching that of the present day, for, apart from the sequent Cretaceous and Tertiary uplift and denudation, the beds e escaped tangential pressure and thermal alteration.

econdly, there are no clear signs either here or elsewhere that strata immediately beneath these basin-shaped sheets have ged down under the influence of the invading magma, and the er is therefore regarded as making its way along an undulating ck, represented in plan by a more or less regular series of 'domes' l 'basins' with a diameter of from 5 to 15 miles and an amplitude from 1000 to over 3000 ft.

undoubted evidence of the existence of similar rock beneath the gabbro cover several miles away to the south. Picrite has been observed, for instance, in the Matatiele district building up an inclined sill, which at a higher level and farther along the outcrop is a normal dolerite, and the more basic facies is actually neither at the extreme base of the intrusion nor in a hollow caused by a local reversal of dip of the latter.

The picrite in the Insizwa workings to which Mr. Goodchild refers was noticed at a later date, and its position there makes it certain that this ultrabasic phase must underlie the range as indicated graphically by him.

It seems likely that the cooling of the magma progressed principally from above downward, and that the picrite arose through the sinking of olivine crystals and was about the last to remain fluid. The mineral banding, so frequently noticed, may, perhaps, be partly due to gravitative action; but at about the upper limit of the picrite at the Tabankulu this character is so marked as to cause the rocks to resemble outwardly archæan gneisses; the fluxion structure has probably been developed through the cake of gabbro pressing upon its partially solidified base, and causing the latter to squeeze outwards—an action aided by movements set up by contraction invoked by the change in volume from the liquid to the solid state.

I have pointed out that the gabbro and norite carry only small amounts of magnetite and ilmenite, considerably less than the normal dolerite. This has obviously been brought about by the replacement of the oxides of iron by sulphides, and the concentration of the latter in the base of the sheet has left the rocks above with a deficiency of iron ores. Mr. Goodchild's demonstration of the abnormal composition of the mineral at Insizwa taken for chalcopyrite may explain the apparent deviation from the order of separation of the sulphides observed elsewhere; the suggestion that this may be due to lower pressure has in its support the fact that the cover at Sudbury must have been at least twice and possibly thrice as thick as that in South Africa.

The paper is welcome both from the scientific and economic aspect, the more so at this juncture when the resources of the Empire are under review.

NOTE.—A geological map (Sheet 27, Geol. Survey of S. Africa) and explanation which embraces the Insizwa area is expected to go to press shortly.

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APRIL 12TH, 1917.

LIST OF CONTENTS.

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LIST OF THE OFFICERS
OF
The Institution of Mining and Metallurgy
1916-1917.

The TWENTY-SIXTH ANNUAL GENERAL MEETING of the Institution of Mining and Metallurgy will be held, by kind permission, at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on THURSDAY, APRIL 19TH, 1917, at **5.30** o'clock p.m.

AGENDA.

(1) Minutes of previous Annual General Meeting.

(2) Appointment of Scrutineers to examine Balloting Papers.

(3) Report of Council and Statements of Accounts for 1916.

(4) Votes of thanks.

(5) Election of Auditors.

At the conclusion of the business of the Annual General Meeting the following Papers, copies of which are attached, will be submitted for discussion :

Stope Measurement at Messina.

By WILLIAM WHYTE, *Associate.*

Platinum in Spain.

By F. GILLMAN, *Member.*

Copies of the Report of Council and Statements of Accounts for 1916 are attached hereto.

The Council invite written contributions to the discussion of Papers from any members who may be unable to be present at the Meetings of the Institution.

Tea, Coffee and Light Refreshments will be provided at 5.0 p.m., for members and visitors attending the Meeting.

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the qualifications of Candidates for Admission into the Institution fulfil the requirements of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be open for inspection at the Office of the Institution for a period of at least two months from the date of the Bulletin in which their applications are announced.

The following have applied for admission since March 15th, 1917:—

To Membership—

Harland, Robert Main (*London*).
Leighton, Ernest William (*London*).

To Associateship—

Cramer, Dwight Lewis (*Tavoy, Lower Burma*).
Glen, Alexander (*Glasgow*).
Hill, John Whitelaw (*Naraguta, Northern Nigeria*).
Loring, Edward Amos (*London*).

The following have applied for Transfer:—

To Membership—

Hutchison, Lawrence George David (*B.E.F.*).

To Associateship—

Hill, Laurence Carr (*B.E.F.*)
Mansfield, Francis Turquand (*B.E.F.*).

ADDRESSES LOST.

F. B. Bradshaw, O. L. de Lissa, D. Nicholas, and J. F. Richards.

WAR SERVICE AND DIPLOMAS.

The Governors of the Imperial College of Science and Technology ve recently considered the conditions to be fulfilled in the case of idents of the Royal School of Mines, whose associateship courses study have been interrupted by their undertaking service with Forces of the Crown, or other approved war work, precedent to award to them of the diploma of Associateship of the Royal iool of Mines in Mining, or in Metallurgy, or in Oil Technology. uch Students are advised to complete the full four-year course hey possibly can, but it is recognised that this will not always ossible, and it has been decided in such cases, as a temporary sure to meet the circumstances arising out of the war, to afford n an opportunity of satisfying the tests ordinarily imposed in than the full time. Each case will be considered and rmined on its merits by the College Authorities, and for their lance certain general principles have been laid down. These ude the contemplation of the possibility of a man completing 1 tests in three years—having regard to experience gained ing the war—and, in that case, the reduction of the require-it as regards practical work (shifts) by one-third, and the sibility of a man making good in certain arrears of subjects ing vacations, but it is considered inadvisable to make any ailment of the work of the first and second years.

ertificates will be granted to those Students who find they not return for the completion of the full course, in which will set forth particulars of the parts previously taken.

MOVEMENTS OF MEMBERS.

'embers of the Institution are invited to send information in regard to their 'ements to the Secretary for insertion under this heading. Members visiting don are requested to register their addresses at the House of the Institution, re the Library, Writing Rooms, etc., are at their disposal.

Ir. Reg. F. Allen, Assoc. Inst. M.M., is returning to England n Northern Nigeria.

Ir. H. C. Bayldon, M. Inst. M.M., has been appointed General nager of the Spassky Copper Properties at Atbasar and Spassky, l his headquarters are now at Spassky (not at Atbasar, as was ted in error in the March *Bulletin*).

MOVEMENTS OF MEMBERS—*continued.*

Mr. H. C. Boydell, Assoc. Inst. M.M., has returned to England from West Africa.

Mr. G. S. Evans, M. Inst. M.M., is returning to England from the Straits Settlements.

Mr. C. Gordon-Helps, Stud. Inst. M.M., is returning to England from West Africa.

Mr. C. S. Pearson, Assoc. Inst. M.M., is returning to England from Northern Nigeria.

Mr. D. Renouf, Assoc. Inst. M.M., has left England for Northern Nigeria.

Mr. Charles C. Scott, M. Inst. M.M., is shortly leaving England for the Straits Settlements.

Mr. A. Stanley Williams, M. Inst. M.M., has returned to England from Northern Nigeria, on leave.

INDEX OF RECENT BOOKS.

NOTE.—Books marked with an asterisk are contained in the Library of the Institution.

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Compressed Air Practice in Mining. D. Penman. London: C. Griffin & Co. 5*s*.

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Significance of Manganese in American Steel Metallurgy. F. H. Willcox.—Bull. No. 122, American Institute of Mining Engineers, New York, February, 1917, pp. 199-207. $1.

Tavoy Wolfram Industry.—Mining Journal, London, Vol. 116, March 24, 1917, pp. 173-5. 6*d*.

Wood Molybdenite Mine, near Quyon, Quebec. J. A. Dresser. — Bull. No. 59, Canadian Mining Institute, Montreal, March, 1917, pp. 206-8.

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Carbonization of Kelp for the recovery of Potash. J. W. Turrentine.—Metallurgical and Chemical Engineering, New York, Vol. 16, February 15, 1917, pp. 196-9. 25*c*.

Chilean Nitrate Industry. A. W. Allen.—Engineering and Mining Journal, New York, Vol. 103, February 3, 1917, pp. 230-3. 15*c*.

Clays and Clay Products of Canada.—Bull. No. 59, Canadian Mining Institute, Montreal, March, 1917, pp. 199-206.

Concrete and Reinforced Concrete. H. M. Wilson. — Transactions, Society of Engineers, London, 1916, pp. 189-60.

Ferro-Cerium and other Pyrophoric Alloys. —Engineering and Mining Journal, New York, Vol. 103, February 3, 1917, p. 212. 15*c*.

Silica Bricks and new uses for them. W. Gray.—Metallurgical and Chemical Engineering, New York, Vol. 16, February 15, 1917, pp. 209-16. 25*c*.

PETROLEUM.

Evidence of the Oklahoma Oil Fields on the Anticlinal Theory. D. Hager.—Bull. No. 122, American Institute of Mining Engineers, New York, February, 1917, pp. 195-8. $1.

Need and advantage of a National Bureau of Well-Log Statistics. W. G. Matteson.—Bull. No. 122, American Institute of Mining Engineers, New York, February, 1917, pp. 287-90. $1.

Spontaneous Ignition Temperatures of Liquid Fuels for Internal Combustion Engines. H. Moore.—Journal, Society of Chemical Industry, London, Vol. 36, February 15, 1917, pp. 109-12. 1*s*. 9*d*.

PLANT AND POWER.

Boiler-house operation and maintenance with special reference to the Rand Power Companies Plant. Discussion. —Journal, South African Institution of Engineers, Johannesburg, Vol. 15, February, 1917, pp. 141-2. 2*s*.

ΞX OF RECENT PAPERS—*continued.*

/ER—continued.

hods at the United F. Richards.—Engi- :k, Vol. 77, February

ɔal Boilers. — Engi- 'ournal, New York, 917, pp. 341-4. 15*c.*

ɔ Air Lift. S. H. ering and Mining 'ol. 103, February 3,

Handling Machinery, cture of Gas. J. E. Society of Engineers,

f a dust-fired Boiler. Society of Chemical l. 36, February 15,

pening shop. J. E. ring and Mining ol. 103, February 10,

of the Whiting hoist nding. B. Gray and :nal, South African ers, Johannesburg, pp. 128-39. 2*s.*

n Vacuum Filtration —Journal, Chamber ustralia, Kalgoorlie, 0, 1916, pp. 291-6.

Temperatures of ternal Combustion -Journal, Society of ndon, Vol. 36, Feb- 2. 1*s.* 9*d.*

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Products and Low- Generation. J. B. C. ical and Chemical k, Vol. 16, February :.

SILVER.

Mining in the Potosi Silver district, Bolivia. B. L. Miller and J. T. Singewald, Junr.—Engineering and Mining Journal, New York, Vol. 103, February 10, 1917, pp. 255-60. 15*c.*

Treatment of certain West Kootenay Silver Ores. F. A. Thompson. — Bull. No. 58, Canadian Mining Institute, Montreal, February, 1917, pp. 165-72.

TIN.

Bucket Dredging for Tin in the Federated Malay States. H. D. Griffiths.—The Mining Magazine, London, Vol. 16, March, 1917, pp. 137-44. 1*s.*

Dolcoath's Profits and Royalties. — The Mining Magazine, London, Vol. 16, March, 1917, pp. 127-8. 1*s.*

Handy Method for Assaying Tin Ores. G. M. Henderson.—Engineering and Mining Journal, New York, Vol. 103, February 10, 1917, p. 267. 15*c.*

Mineral Resources of the British Empire: Tin. C. G. Cullis.—Transactions, Society of Engineers, London, 1916, pp. 240-50.

New developments in the Porco Tin district, Bolivia. J. T. Singewald, Junr., and B. L. Miller.—Engineering and Mining Journal, New York, Vol. 103, February 24, 1917, pp. 329-33. 15*c.*

Properties of Bronzes for mechanical purposes. H. S. Gulick.—Metal Industry, London, Vol. 10, March 16, 1917, pp. 257-9. 4*d.*

Tin Assays.—The Mining Magazine, London, Vol. 16, March, 1917, pp. 181-2. 1*s.*

MILITARY SERVICE.

SUPPLEMENTARY LIST.

ollowing have been notified since the issue of the last Bulletin, 15th, 1917:

MEMBERS SERVING WITH H.M. FORCES.

7. (*No particulars.*)
JAMES G., King's African Rifles.
. C., London Regiment (Artists' Rifles).
J. V., Royal Engineers, (2nd Lieut).
Royal Engineers, (Captain).
AMES, Royal Engineers, (2nd Lieut.).
I. C., Royal Garrison Artillery, (2nd Lieut.).
H. WARINGTON, Royal Naval Volunteer Reserve, (Lieut.).
J. H. G., Royal Engineers, (2nd Lieut.).

PROMOTIONS OR OTHER CHANGES.

, C. A., Royal Engineers, (Major).
. C., Duke of Cornwall's Light Infantry, (Captain).
DICKSON, E. J., Royal Engineers, (Captain).
N, R. C., Royal Engineers, (Captain).
, W. A., Australian Imperial Forces, (2nd Lieut.).

KILLED IN ACTION.

MORRIS BRITTAIN, *Associate*, Orderly, Royal Army Medical Corps, (*Died Cholera in Mesopotamia on July 2nd, 1916.*)

GAVEY MCKEOWN, *Student*, Engine-room Artificer, Royal Navy. (*No ticulars.*)

CROWTHER & GOODMAN, LTD., Printers, 124, Fenchurch Street, London, E.C. 3.

Subject to Revision.]

THE INSTITUTION OF MINING AND METALLURGY.

TWENTY-SIXTH ANNUAL REPORT OF COUNCIL.

In common with other organizations, the affairs of the Institution of Mining and Metallurgy during the year ended December 31st, 1916, were conducted under increasingly difficult conditions, but the Council have the satisfaction of stating that notwithstanding this fact, the interest of members have been conserved and much work of National importance has been accomplished which they believe will have far-reaching effects upon the future of the mining and metallurgical industries of the Empire. The Institution and its executive officers have also been able to render useful services in connection with the War.

The position of the domestic affairs of the Institution at the end of the year 1916 can only be considered as satisfactory having regard to the fact that so large a proportion of the members are on Active Service with His Majesty's Forces or engaged in other War services.

This is not the time to do more than make a passing reference to the large number of members who at the call of duty have voluntarily relinquished their positions, in many cases at great material sacrifice, and have returned home from all parts of the world to join the Imperial Forces or those of the Dominions; but the Council cannot refrain from expressing their admiration of the splendid spirit shown by their fellow-members of the Institution and their keen appreciation of the manner in which they have upheld the highest traditions of the Mining Profession as evidenced by their achievements and by the large number of distinctions that have been won.

Scientific and Industrial Research.

In their Report for 1915, the Council referred to the fact that the Institution had accepted an invitation to co-operate in the work of the Committee of the Privy Council for Scientific and Industrial Research. Messrs. Edgar Taylor, Edward Hooper, H. L. Sulman and F. W. Harbord have since been appointed as the

Official Representatives of the Institution on the Metalliferous Mining and Non-ferrous Metallurgical Committees constituted by the Research Advisory Council.

On the invitation of a representative meeting held in Cornwall, under the auspices of the Royal Cornwall Polytechnic Society, the Council undertook, with the approval of the Committee of the Privy Council, to direct an investigation into the existing methods of extraction and economic production of tin and tungsten, with special reference to Cornwall, with the object of ascertaining the percentage of actual recovery of metal contents, of co-ordinating and completing researches already begun and, if necessary, of instituting others on new lines and of suggesting improved or new methods of treatment. The cost of the research will be defrayed by grants from the Privy Council Committee, supplemented by contributions from the Royal Cornwall Polytechnic Society, representing the county of Cornwall, and the Institution of Mining and Metallurgy.

The research is being conducted by the Tin and Tungsten Research Direction Committee, which is constituted as follows:

Sir Thomas K. Rose (*Chairman*).
Mr. W. H. Trewartha-James (*Hon. Director*).
Mr. H. K. Picard.
Professor S. J. Truscott.
*Mr. Henry Jenner (*President of the Royal Cornwall Polytechnic Society*).
*Mr. R. Arthur Thomas.
*Mr. Josiah Paull.
*Mr. William Thomas (of Tincroft).
Mr. C. McDermid (*Secretary*).

A large amount of work has already been carried out and the Council confidently look for valuable results from the investigation. They desire to record their thanks to the Governing Body of the Imperial College of Science and Technology for granting facilities for much of the work to be conducted at the College and for bearing the cost of part of it. They also desire to record their thanks to the Professors in the various Departments of the College for their valuable co-operation.

**Representing the County of Cornwall.*

Government Committees on Commercial and Industrial Policy.

In response to an invitation from the Iron, Steel and Engineering ndustries Committee, the Council expressed, in a written statement, heir views upon various questions relating to the mineral resources f the Empire and its dependence upon foreign countries for mineral r metal supplies previous to the War and the measures which hould be adopted to ensure the development of British mineral esources in the interests of the Empire. The following repre-entatives attended before the Committee to give evidence in mplification of the views of the Council in their corporate apacity: Sir Thomas K. Rose, Messrs. Edward Hooper, J. H. ordner-James, H. K. Picard and C. McDermid (*Secretary*).

The President, Mr. Edgar Taylor, and the Secretary also attended efore the Committee on Commercial and Industrial Policy, with epresentatives of the Iron and Steel Institute, to give evidence on he question of the organization of the mineral resources and ndustries of the Empire.

Proposed Department of Minerals and Metals.

The Council have for some time past given close attention to the uestion of the establishment of a Department of Minerals and Metals in the Metropolis of the Empire, to collect and co-ordinate nformation relating to the mineral resources, to stimulate its lissemination and to advise upon measures for protecting and xtending the mining and metal industries in the manner best alculated to promote the National safety and welfare.

The question was informally discussed in 1915, with the Execu-ive Officers of the Research Advisory Council, and subsequently vith the representatives of other Government Departments and the mperial Institute.

These informal discussions were followed by a Conference of fficial representatives of the Iron and Steel Institute, the Institute f Metals, the Institution of Mining Engineers, and the Institution f Mining and Metallurgy, held on the invitation of the Council of he Institution. As a result of this Conference, the proposal mbodied in the following Memorandum was formally submitted to he Councils of the four Institutions, unanimously adopted by hem, and transmitted to the Government:—

PROPOSED DEPARTMENT OF MINERALS AND METALS.

LONDON,
September 22nd, 1916.

To Sir WILLIAM S. McCORMICK,
Chairman,
Advisory Council for Scientific
and Industrial Research.

SIR,

On behalf and by authority of the Councils of the following Institutions:

THE IRON AND STEEL INSTITUTE
(Incorporated by Royal Charter as representing the Iron and Steel Industries);

THE INSTITUTE OF METALS
(Incorporated as representing the users and manufacturers of non-ferrous metals and alloys);

THE INSTITUTION OF MINING ENGINEERS
(Incorporated by Royal Charter as representing Coal and Iron Ore mining and allied industries); and

THE INSTITUTION OF MINING AND METALLURGY
(Incorporated by Royal Charter as representing the mining of minerals other than Coal and Iron Ores and the production of metals other than Iron and Steel);

WE, the undersigned, have the honour to submit the following considerations and recommendations in the hope that through the intervention of the Committee of the Privy Council for Scientific and Industrial Research, measures may be taken to provide the necessary machinery for the protection and advancement of the economic welfare of the mineral and metal industries of the Empire.

The absence of effective co-ordination of the organizations of these vital industries has been demonstrated and brought into prominence by the War, in many directions. The grave results to the National interests are generally admitted.

There are highly organized Geological Surveys and Departments of Mines in nearly all foreign countries, and their influence in the development of mineral resources is a factor of the first importance. There are similar well-organized Departments in some of the British Dominions, but there is no connecting link or central 'clearing-house' in the Metropolis of the Empire to co-ordinate information on its mineral resources, to stimulate their development and to safeguard Imperial interests.

Various Departments of the Home Government, such as the Geological Surveys and Museum of Practical Geology, the Board of Trade, the Home Office, the Imperial Institute, and, since the outbreak of the present War, the Foreign Office, the Admiralty, the War Office, and the Ministry of Munitions, have all been concerned with the collection of information bearing on the sources of supply of minerals and the pro-

duction of metals. There does not appear, however, to have been any serious attempt to co-ordinate and render available even such information as has been collected by these Departments, and it is certain that there has been considerable overlapping and duplication of effort with corresponding waste and confusion.

It is, we submit, obvious that the overlapping and confusion will be seriously increased if the various Technical Committees appointed by the Advisory Council attempt to collect the information which is essential to enable the beneficent object of the Committee of the Privy Council to be attained, in its wider aspects, in regard to the mineral and metal industries.

We respectfully urge this view upon the serious attention of the Advisory Council, as already there are evidences of increasing overlapping and consequent waste of time and energy, which we believe it is one of the main purposes of the Committee of the Privy Council to eliminate as far as possible.

In the opinion of the Institutions represented by us the organization of a central Department of Minerals and Metals is imperatively necessary in the public interest, and the work of organization, which will necessarily take much time to complete, should be commenced at the earliest possible moment.

It cannot be doubted that if a properly organized and efficiently conducted Department of Minerals and Metals had been in existence, much valuable time, many lives and vast sums of money would have been saved to the Nation in the conduct of the present War, and much of the cost and inconvenience to British Industries depending largely for their raw materials on mineral products would have been saved, with corresponding advantages to the prosecution of the War and to many industries.

A Department of Minerals and Metals should not only be in intimate relationship with the Geological Surveys and Mines Departments of the Dominions, but also with the organizations representing the different branches of the mining and metallurgical industries, whose co-operation in the work of the Department should form a vital part of its machinery.

The Geological Surveys of Great Britain and Ireland and the Museum of Practical Geology should also form an integral part of the Department.

The functions of the Department should be active and constructive. All overlapping by other Home Government departments, and also by the Institutions representing the Industries, should be absolutely prevented.

The duties of a Department of Minerals and Metals would include:

1. Arrangements for expediting the completion of Mineral Surveys of the United Kingdom and of the Crown Colonies and other British Possessions.

2. The systematic collection and co-ordination of information bearing on the occurrence, uses and economic value of minerals and their products; special attention being devoted to securing

industrial applications for newly-discovered minerals or metallurgical products and to finding mineral materials required for new metallurgical products or inventions. Some of this information should be promptly and widely disseminated in summarized form to those interested in the industries, through the medium of the existing publications of the Institutions directly concerned.

3. The investigation of all questions and problems relating to the utilization of the mineral or metallurgical resources of the Empire.

4. The co-ordination and dissemination of information on mining laws, development of mineral areas, output, processes of extraction, plant, capital employed, markets, etc., etc.

5. A general review from time to time of the developed and undeveloped mineral resources and of the position of each mineral or metal to ensure that the mineral wealth of the Empire is being exploited with due regard to Imperial interests.

6. Generally, to advise the Imperial Government on all questions bearing on the mining and metallurgical industries. To perform this function efficiently, it is essential that complete information should be available, and also that the industries concerned should be consulted through their respective organizations.

We feel sure that the Advisory Council will fully appreciate the urgency of the question and the necessity for prompt action, so that the process of co-ordination may be inaugurated at once.

We are, Sir,
Your obedient Servants,

WM. BEARDMORE, *President* G. C. LLOYD, *Secretary*	The Iron and Steel Institute.
GEORGE BEILBY, *President* G. SHAW SCOTT, *Secretary*	The Institute of Metals.
W. THORNEYCROFT, *President* L. T. O'SHEA, *Hon. Secretary* P. STRZELECKI, *Secretary*	The Institution of Mining Engineers.
EDGAR TAYLOR, *President* C. MCDERMID, *Secretary*	The Institution of Mining and Metallurgy.

The proposal was referred by the Imperial Government to the Committee on Commercial and Industrial Policy for consideration and report, and the representatives of the Institutions concerned have elaborated the proposal in evidence before the Committee, and by additional communications in writing.

The proposal has also been considered by the Dominions Royal Commission and by the Governments of the Dominions, most of which have already formally expressed their cordial approval. The Council trust that a central organization will be established in the near future.

Taxation of the Mining Industry.

The Joint Committee appointed at a meeting of representatives of Mining Companies in August, 1916, of which an abridged report was issued with the September *Bulletin*, to act with the Council of the Institution in an endeavour to obtain an adjustment of the incidence of taxation on the Mining Industry, with immediate reference to the Excess Profits Duty, has held numerous meetings and has had conferences with the Board of Inland Revenue and the Board of Referees (appointed under the Finance (No. 2) Act, 1915), with a view to facilitating procedure by their acceptance of certain general principles dealing with special risk, duration of life and amortization of capital.

As a result the Board of Inland Revenue have intimated that they are prepared to accept the Committee's contention that mines are wasting assets, and that amortization of capital should be allowed.

At the request of the Board of Inland Revenue, cases are in course of preparation by the Committee for two representative Appeals.* The amount of statistical information required by the Revenue Authorities to establish a claim for an increase of the statutory percentage of 6 % allowed by the Act, entails a large amount of investigation, but the Council have reason to hope

* It may be of interest to members to know that decisions have already been given by the Board of Referees in independent applications for an increase in the statutory percentage (6 %) in the following cases:

Gold-mining in Rhodesia—Increased to 22½ %.

Alluvial Tin-mining in the Malay States—Increased to 13 % for companies.

Alluvial Tin-mining in Nigeria—Increased to 13 % for companies.

Chrome-mining in India—Increased to 22½ %.

that succeeding cases will be facilitated when the Appeals now in course of preparation have been decided.

The Joint Committee in charge of the matter is constituted as follows:

Mr. John H. Cordner-James (*Chairman*), Lord Harris, Sir Lionel Phillips, Bart., Sir Alfred Mond, Bart., P.C., M.P., Sir Trevredyn R. Wynne, Messrs. F. W. Baker, Edmund Davis, F. A. Govett, F. H. Hamilton, Edward Hooper, E. W. Janson, Edgar Taylor, Henry C. Taylor, Leslie Urquhart, Stephen Vivian, and Oliver Wethered.

Roll of the Institution.

During the year 72 members were admitted into the Institution (including two Hon. Members), and there were 48 transfers to Associateship or Membership, as compared with 72 and 46 respectively in the previous year. The total membership at December 31st, 1916, was 2409, as compared with 2441 at December 31st, 1915—a decrease of 32.

Nine Members, thirteen Associates and ten Students were removed from the roll in consequence of the non-payment of arrears of their subscriptions; the resignations of thirteen Members, six Associates and three Students were received and accepted; and seven Students were removed through failure to obtain transfer to Associateship within the period required by the By-Laws.

The Council record with a deep sense of loss to the Profession the fact that during 1916 twenty-five Members were reported as having lost their lives in the War; and they also record with regret the decease of two Honorary Members, seven Members, seven Associates and two Students. Their names are as follows:

Killed in Action.

Associates:—Major J. N. F. Armstrong, 2nd Lieut. Humphry L. Braithwaite, Lieut. Frederick Crathorne, 2nd Lieut. W. J. N. Dunnachie, Lieut. W. Macleish Durant, 2nd Lieut. Ernest E. Glorney, 2nd Lieut. A. Downing Johnson, Captain Patrick A. Murray, 2nd Lieut. A. Limnell Robinson, Lieut. George Simpson, Junr., 2nd Lieut. James C. Simpson, Major D. M. Tomlinson, 2nd Lieut. Raymond B. Williams, M.C., 2nd. Lieut. George de Wolf.

Students :—2nd Lieut. Donald F. Beckhuson, 2nd Lieut. John Ivor Grey, Lieut. Laurence C. Hatch, 2nd Lieut. J. McMaster Hutchison, Lieut. Amyas MacGregor, M.C., Sergeant James McNeill, Junr., 2nd Lieut. Evelyn S. Marshall, 2nd Lieut. Mansfeldt C. N. Mills, 2nd Lieut. John Philpot, Captain Philip S. Picot, 2nd Lieut. George J. Roberts.

DEATH FROM OTHER CAUSES.

Hon. Members :—Professor John Wesley Judd, C.B., LL.D., F.R.S., and Joseph Henry Collins, *Past-President.*

Members :—Percy E. Ogle Carr, George Deer, Arthur Gifford, G. Hamilton Lloyd, Bedford McNeill (*Past-President*), D. D. Rosewarne, Richard Stanton.

Associates :—William J. Burley, Owen Jones, Albert C. Perveil, Wilfred H. Rigg, Joseph D. Small, C. Harold Turrell, J. Wilson Williams.

Students :—Guy O. Canning, William H. Marston.

The following is a list of the Hon. Members, Members, Associates a Students admitted into the Institution during the year:

Hon. Members :—Surgeon-General Sir Alfred Keogh, Professor ·nry Louis Le Chatelier.

Members :—Thomas Andrews, William B. Ballantine, William C. Blackett, Alfred L. Blomfield, Arthur H. M. Brown, J. Coggin Brown, James Caldwell, Charles V. Corless, Angus W. Davis, John W. Fetherstonhaugh, Alejandro López, G. Auguste Michel, Walter E. Segsworth, M. Thomas Taylor, William Walker, James G. West, Leslie B. Williams.

Associates :—William Body, Angus L. Butler, Arthur Davies, Cyril N. Davies, Victor T. Edquist, Carl Fox, Arthur C. Gaved, Frank Hetherington, Tom C. L. Howard, George Howatson, William R. Jones, Matthew L. Lowden, Thomas F. Maddick, T. H. Carter Mitchell, Charles A. Mitke, Algernon H. Moreing, Bertram Morton, Cyril B. North, Walter Perring, Brindley T. Phillips, William W. Raymond, Allan D. Robinson, Charles W. Roe, William J. Russell, Herbert J. Sparks, Sidney H. Steels, Thomas J. Taplin, Junr., John B. W. O. Williams-Jerrard.

Students:—John M. Adamson, Victor J. Akylas, Albert E. Andrews, José B. Bebiano, Fernando A. C. Benitez y González, Percy Bonds, Charles R. Chaffey, Zur-Chong Chen, Philip C. Collins, George W. Cradduck, Charles A. F. Davey, Ralph John Harrison, George Sydney Harris, Rupert C. C. Irving, Bernard C. Job, Edward L. Johnson, Reginald O. Podger, Harold W. Poulter, Alan R. Powell, Edward J. Quayle-Dickson, Herbert J. Robertson, William J. Rogers, Bertram Siddons, Elias Werchowsky, Ernest W. Woodfield.

The following have been transferred:

To Membership:—Charles A. Banks, David H. Bannerman, W. R. Coleridge Beadon, William Birch Blyth, Gilmour E. Brown, Gordon S. Duncan, G. Stephen Evans, James Hogg, Joseph H. Ivey, William Kitto, Robert Lee, Harold A. Lewis, Frederick J. Tonks, Edward H. Watson.

To Associateship:—Hirzel A. Adams, Milton A. Allen, William T. Anderson, Walter Beringer, Arthur P. Catherall, John A. Child, Reuben H. Conran, Horace G. Elston, Herbert Eyden, Oswald Fernie, Arthur H. P. FitzPatrick, Colin P. Flockart, Arthur E. Flynn, Richard V. Garland, Donald Gill, Archibald G. Glenister, Madan M. Goswami, Harold Greatwood, Norman R. Harper, G. Hildick-Smith, William J. Howes, John S. Hutt, F. R. Lanfear Miller, Robert J. Morgan, Herbert L. Morton, Rupert F. Scrivener, William T. Smith, George E. Stott, Stanley Tucker, Basil M. Venables, Thomas R. Weir, Gordon Wells, Benjamin H. Wood, Montefiore P. Woolf.

The following are the Resolutions recording the election to Hon. Membership of Sir Alfred Keogh and M. Henry Louis Le Chatelier:

(1) That Surgeon-General Sir Alfred Keogh, K.C.B., Rector of the Imperial College of Science and Technology, Acting Director-General of the Army Medical Service, be and is hereby elected an Honorary Member of the Institution of Mining and Metallurgy in recognition of his eminent services to the Cause of Scientific and Technological Education, and of his devotion to public duty as Acting Director of the Medical Department of His Majesty's Army during the present War.

(2) That M. Henry Louis Le Chatelier, Chevalier of the Legion of Honour, Member of the Institute of France, etc., etc., be and is hereby elected an Honorary Member of the Institution of Mining and Metallurgy in recognition of his great services to Science and to the Metallurgical Industries.

AWARDS.

As in 1915, in consequence of the War, the award of Medals, emiums, Post-Graduate Scholarships, and Prizes, remained in eyance.

ELECTION OF PRESIDENT, TREASURER, VICE-PRESIDENTS AND MEMBERS OF COUNCIL.

As previously announced, Sir Richard Redmayne felt it difficult, a Government servant, to retain the Presidency, in view of the t that the Institution was dealing with questions affecting cation, the formation of a Department of Minerals and Metals, :. Sir Richard's resignation was accepted by the Council with eat regret in August, and Mr. Edgar Taylor, Past-President and easurer, at the request of his colleagues, consented to re-election President for the unexpired period of Sir Richard Redmayne's m of office, and he has been elected for a further term ending in rch, 1918. Mr. Edgar Taylor has been re-elected as Treasurer the period ending in March, 1918, and Messrs. J. H. Cordner-mes, F. W. Harbord, G. T. Holloway, E. T. McCarthy, Frank rricks and H. M. Morgans have been re-elected as Vice-Presidents the same period.

Mr. W. A. Carlyle resigned his seat on the Council, owing to sence from England for an extended period. Sir Robert A. dfield, Mr. J. C. Moulden, Mr. Leslie Urquhart, and Mr. R. thur Thomas were elected Members of Council for the period ding in March, 1917, and they have been nominated for re-ction at the Annual General Meeting.

LIBRARY.

The Council desire to record their thanks to those who have esented books or other works to the Library. They also record eir thanks to Mr. George T. Holloway for his valuable gift to the stitution of the original drawing of the late Dr. John Percy, F.R.S., J. Gilbert (1859); and to Mrs. Peter Watson and Mr. William isholm for a box of mineral specimens, collected in the British les by the late Peter Watson.

Meetings and Publications.

During the year six General Meetings were held at the Rooms of the Geological Society in Burlington House, and the Council record their sense of indebtedness to the Council of the Society for their continued hospitality for the General Meetings of the Institution.

Sixty Council and Committee Meetings were held during the year, in addition to a large number of Conferences, which were attended by Committees and the Executive Officers.

The *Bulletin* and *Transactions* were issued as usual, but the Council felt it necessary, both on National and financial grounds, to curtail the number of papers issued during the Sessional year ended September 30th, 1916, Volume XXV of the *Transactions*, which is now in the press, containing about 400 pages as against 553 pages in the previous volume.

Annual Dinner.

The Annual Dinner of the Institution was not held in consequence of the War; but members dined together, informally, on Thursday, February 24th, 1916, under the Chairmanship of the President, Sir Thomas Kirke Rose.

Accounts.

The Statements of Accounts, submitted herewith, show the or- nary receipts for the year ended December 31st, 1916, to have be- 4636*l*. 13*s*. 3*d*. as compared with 4906*l*. 2*s*. 10*d*. in 1915, a decre- of 269*l*. 9*s*. 7*d*. The ordinary expenditure amounted to 4332*l*. 8*s*. 1- as compared with 4666*l*. 0*s*. 10*d*. in 1915, a decrease of 333*l*. 12*s*. 9- These figures must be regarded as satisfactory.

EDGAR TAYLOR, *Presiden-*

C. McDERMID, *Secretary*.

April 12*th*, 1917.

Ordinary Account.

Dr. *Receipts and Expenditure for Year ended December 31st, 1916.* **Cr.**

Expenditure.	£	s.	d.
To Cost of *Transactions* (*for sessional year ended September 30th, 1916*)	904	19	2
,, Printing and Stationery (*for sessional year ended September 30th, 1916*)	188	16	9
,, Cost of *Bulletin* (*for sessional year ended September 30th, 1916*)	219	10	6
,, Meeting and Informal Dinner Expenses	68	19	11
,, Rates, Taxes and Insurance	208	4	2
,, Heating and Lighting	44	6	10
,, House Expenses	26	17	3
,, Telephone	31	14	10
,, Audit Fee	31	10	0
,, Salaries and Wages (*including allowances to members of the staff on Active Service*)	1,981	7	0
,, Postage and Receipt Stamps	220	0	0
,, Sundry Expenses (including travelling, etc., expenses and repairs)	147	13	9
,, Interest on Bank Overdraft	57	15	0
,, Interest on Post-Graduate Grants Fund	12	2	0
,, Depreciation—Furniture and Library	188	10	11
,, Accumulated Fund—Excess of Receipts over Expenditure for the year ended December 31st, 1916	304	5	2
	£4,636	**13**	**3**

Receipts.	£	s.	d.	£	s.	d.	£	s.	d.
By Entrance Fees and Subscriptions—									
Entrance Fees				210		0			
Subscriptions	£3,950	7	0						
,, (Life Compositions)*	47	5	0						
				3,997	12	0			
							4,207	12	0
,, Sales of *Transactions*							120	12	4
,, Interest and Dividends							308	8	11
							£4,636	**13**	**3**

* Transferred to Life Compositions Capital Account.

THE INSTITUTION OF MINING AND METALLURGY.

SPECIAL FUND.

DR. *Receipts and Expenditure for Year ended December 31st, 1916.* CR.

EXPENDITURE.	£ s. d.	RECEIPTS.	£ s. d.
To Balance carried to Balance Sheet	28 1 0	By Balance from December 31st, 1915	28 1 0
	£28 1 0		£28 1 0

POST-GRADUATE GRANTS TRUST FUND.

DR. *Receipts and Expenditure for Year ended December 31st, 1916.* CR.

EXPENDITURE.	£ s. d.	RECEIPTS.	£ s. d.
To Balance carried to Balance Sheet	415 18 0	By Balance of Gifts of £1,025 from Mr. Hennen Jennings and the late Arthur C. Claudet ..	363 16 0
		" Amount of Grant refunded	40 0 0
		" One year's Interest at 3 % on £403 16s. 0d. ..	12 2 0
	£415 18 0		£415 18 0

		£ s. d.	£ s. d.
To Sir Julius Wernher Memorial Fund ..			10,000 0 0
,, Special Fund		28 1 0	
,, Post-Graduate Grants Trust Fund ..		415 18 0	
			443 19 0
,, Life Compositions Account			2,168 5 0
,, Accumulated Fund: Balance December 31st, 1915	£7,857 10 2		
Add Twenty-first Anniversary Fund Receipts during 1916	9 9 0		
Add Excess of Receipts over Expenditure for the year ended December 31st, 1916	304 5 2		
		8,171 4 4	
Deduct Transfer to Life Compositions Account		47 5 0	
			8,123 19 4
,, Sundry Creditors (*Transactions* Account)			430 0 0
,, Suspense Account (Subscription paid into Bank—name of member unknown)			1 11 6
,, Advance by Bankers (secured by deposit of Deeds of No. 1, Finsbury Circus)			1,451 13 5
			£22,619 8 3

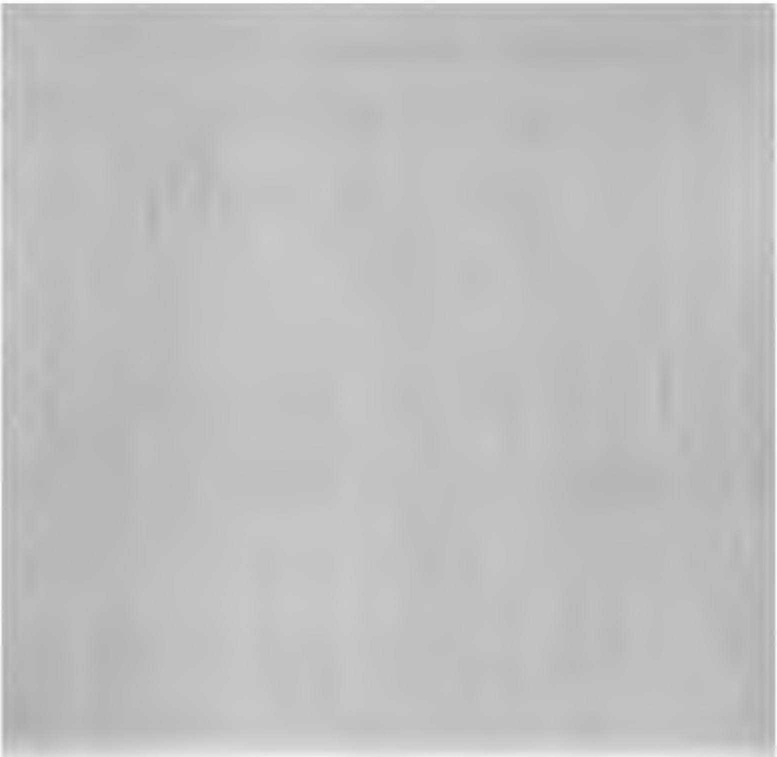
		£ s. d.	£ s. d.
By Investments—Sir Julius Wernher Memorial Fund:			
£502 London and South Western Railway 3 % Consolidated Debenture Stock		388 8 5	
£2,250 London County 3 % Consolidated Stock		1,715 12 6	
£1,971 9s. 2½ % Consolidated Stock		1,442 19 1	
£4,000 Union of South Africa 4 % Consolidated Stock ..		3,965 4 10	
£2,500 Newfoundland 4 % Inscribed Stock		2,487 15 2	
			10,000 0 0
,, Freehold Property, No. 1, Finsbury Circus, E.C.			11,049 11 6
,, Furniture and Library as per last Balance Sheet	£1,454 15 4		
,, Additions during 1916 ..	53 12 4		
		1,508 7 8	
Less Depreciation at 12½ % ..		188 10 11	
			1,319 16 9
,, Sundry Debtors (Tin and Tungsten Research)			50 0 0
,, Cash in hands of Secretary (Petty Cash Account)			200 0 0
			£22,619 8 3

EDGAR TAYLOR, *Treasurer*.
C. McDERMID, *Secretary*.

We have examined the foregoing Balance Sheet with the Books, vouchers and securities of the Institution, and certify it to be in accordance therewith. The value of the *Transactions* in hand, and the subscriptions in arrear, are not included among the assets.

WOODTHORPE, BEVAN & CO., Chartered Accountants, *Auditors*.

London, *April 12th*, 1917.



CONTRIBUTED REMARKS

ON

'Hydraulic Tin Mining in Swaziland.'

By J. JERVIS GARRARD, *Member.*

[r. E. T. McCarthy: Mr. Garrard's paper is undoubtedly .nusual interest, and must appeal to all of us who are in- 3ted in alluvial works, whether in tin or gold.

he conservation of the somewhat restricted supply of water, the methods by which it has so skilfully been utilized, to in the utmost limits of its usefulness, both for washing and er purposes, are features that stand out pre-eminently in the tical working of these tin deposits.

ı 1899 I spent about four hours on the property when returning ı Bremersdorp, the then capital of Swaziland. At that time e workings were locally known as the 'Bryan Tin Workings.' und Mr. Bryan, with some 40–50 Kaffirs, engaged in uncover- and sluicing down the detritus in the upper part of one of the ks, where he had exposed a face of decomposed granite which all the appearance of a stock-werke, or of small tin-carrying .s running throughout it.

[y attention at the time was more particularly directed to the overy of the tin itself and the results obtained in the sluice əs; it being then, so far as I knew, the first discovery of tin South Africa, which probably led to the subsequent discoveries ;in in the Transvaal itself and in Cape Colony.

can confirm the author's statement that their method of work- was crude, for they had already badly blocked up the lower end their workings with tailings, and there was much handling and ıandling of them in consequence.

:t was my intention to have returned later, but the Boer War ke out almost immediately afterwards.

'rom hasty inspection I was satisfied there was tin probably in ing quantities, as even with their rough and ready methods they e more than making ends meet.

remember being struck with the amount of monazite sands nd at the head of the sluice boxes, and as a matter of interest I ıld like to ask the author if these sands are still found in appre- ıle, or even commercial quantities.

[r. Bryan was, I believe, the discoverer and pioneer of these tin osits, and for several years worked the concession on a very ited scale, and under great disadvantages. Subsequently I lost ıt of what was being done, until I read in the papers long after-

wards that Mr. Douglas Osborne was being sent out to report on the concession with a view to improving on its methods of washing down the alluvial.

No better selection, in my opinion, could have been made, as he was an engineer whose many years' experience, in the Malay States, of alluvial workings under almost every conceivable condition, whether by ground sluicing, hydraulicking, hydraulic elevating, gravel pumping, or dredging, were exceptionally unique.

I note that a great advance has been made from that period by a process of development until to-day it has attained, perhaps, its highest limits under Mr. Garrard's able direction.

It has been a great surprise to me to hear of the way in which all the available streams have been collected and utilized to extract the greatest service out of them. From my cursory visit I came to the conclusion, at the time, that want of water would prevent the possibility of developing the concession into anything like a large undertaking. Again I would remark that the way in which almost insuperable difficulties in this direction have been mastered does Mr. Garrard the greatest credit.

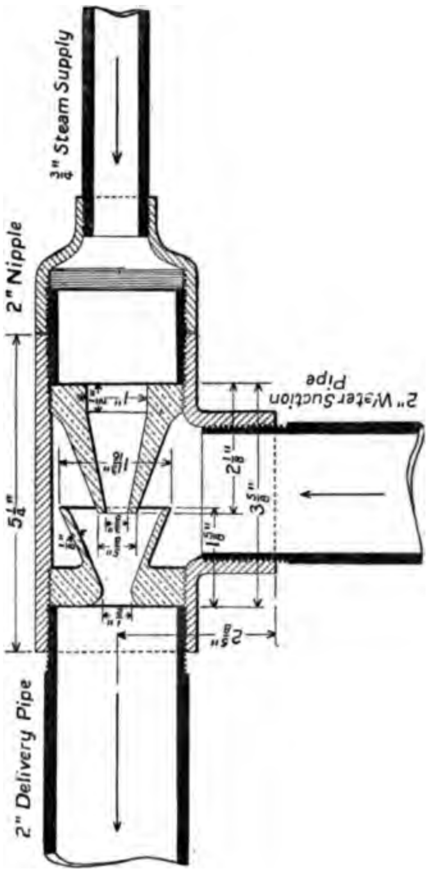
I should like, therefore, to add my quota of praise of the very valuable paper, not only for the practical details given in it, but also for the excellent perspective in which it has been drawn up, dealing as it does so concisely with each subject under its own special heading.

Also I would point out that the Institution is under a great obligation to the Board of the 'Swazie Tin Limited' Co. for having allowed such minute details of construction and costs to be published, thereby initiating a policy which, if adopted by other companies, would be of great advantage to engineers engaged in similar mining and metallurgical work. At present, unfortunately, experience which would be of inestimable value is locked up by the generality of Boards of Companies through a narrow-sighted and microscopic view of things. For example, a record of the failures and successes experienced by the Rio Tinto Co., had it been given to the mining profession, would have been an immense contribution to the advancement of both mining and metallurgical science.

Mr. Humphrey M. Morgans: Mr. Garrard's paper is of excellent quality. It is most refreshing and stimulating to come across officials who keep such close and detailed records of work done as is shown to be the case in this paper. A perusal of the paper inspires confidence in the accuracy of the work, which will be most useful in our *Transactions* for reference.

ıe thanks of all are due to the author, and also to the Company are so liberal-minded as to consent to the publication of the ıls.

ıe paper describes a remarkable development of up-to-date ıods in a very out-of-the-way situation. The total capital ıy involved must be considerable. It is not clear, I think,



Section of Steam Ejector made from ordinary 2-in. T-piece.

.her in the figures of cost is included amortizement of capital. ı the tabulation, Appendix B, it appears that the cost of wals and replacements is not included.

ıe water ejector is used for raising both a mixture of water and ıl, and water alone. The efficiency is very low—under 20 % e paper shows—but this result does not condemn the apparatus,

because it is most simple and cheap to operate and uses power which would otherwise be wasted.

The drawing accompanying these remarks shows a simple ejector that can be made up of ordinary pipes for use in draining shallow pits or trenches by the aid of steam.

Another use for a water ejector which may be mentioned is at the bottom of a sinking pit. The pump is placed above the shaft bottom out of the way of flying stones caused by firing shots, and draws its supply from a slung tank. The tank is replenished by an ejector placed near the shaft bottom. Power for the ejector is obtained by a connection with the pump rising main, through which a portion of the water passed by the pump is taken to the ejector, of course under pressure, and there draws in the water made in the bottom, and both power water and pit bottom water are delivered to the slung tank.

The advantage of this arrangement is, that even when the suction pipe of the ejector gets on air the apparatus continues to work.

A successful centrifugal gravel pump seems to have been found. Details of this pump, which the author does not give, would be of great interest to all engineers having to deal with mixtures of water and gravel.

Aluminium wire is used for the overhead bare electrical transmission system, and it is most interesting to learn that the lines worked out cheaper in aluminium than they would have done in copper. This is not by any means always the case, and copper is much easier to deal with in the matters of jointing, sweating, etc.

There are some dimensions on the drawing of the monitor in Fig. 8, and a scale is shown for all the drawings. It would, however, be very useful if the views of the hydraulic elevator and water elevator were dimensioned.

Crowther & Goodman, Ltd., Printers, 124, Fenchurch Street, London, E.C. 3.

The Institution as a body is not responsible for the Statements or Opinions expressed in any of its Publications.

Subject to revision.] [*A Paper to be discussed at a Meeting of the Institution of Mining and Metallurgy, to be held at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on Thursday, April 19th, 1917, at 5.30 o'clock p.m.*]

Stope Measurement at Messina.

By William Whyte, *Associate.*

Certain of the stopes at the Messina Copper Mine in the Northern Transvaal presented great difficulties when attempts were made to survey them in detail by ordinary methods, and, in order to obtain reliable records, a special procedure had to be devised.

The orebodies in these stopes are irregular, almost vertical shoots of large cross-section. In some of the stopes a horizontal slice about 7 ft. or 8 ft. high is removed and the cavity filled currently with waste rock, while in the remainder a shrinkage method is used. In both cases the problem is similar.

Prior to stoping, winzes are sunk through the ore to act as air-ways, and waste-passes, and, as the ore is stoped, double-compartment passes of timber cribbing are carried through the filling as nearly vertical as possible—one compartment being used as an ore pass, and the other as a manway.

A space of about 18 in. is usually left above the filling, through which it is possible to crawl and reach the back.

The ore is generally too soft to stand without temporary timber supports, and these are very numerous in heavy ground.

The first slice ('sill') of any stope is horizontal but the back often becomes inclined as stoping proceeds, and may vary considerably in elevation.

It was considered that only methods which gave accurate horizontal cross-sections ('contours') of the shoots at regular intervals would be satisfactory.

Methods involving the use of a theodolite were discarded for the following reasons: (*a*) frequency of insufficient height to work the instrument with the ease and rapidity necessary for economic stope measurement, (*b*) trouble due to interference by timbers, (*c*) difficulties incidental to connecting stope surveys with development surveys through long, narrow passes, and, (*d*) necessity of using as assistants, Kaffirs who could not be trusted to work reliably at more than, say, 20 ft. from the observer. In the method finally decided

upon, the hanging compass and clinometer are used for the necessary traverses, and the polar protractor for details.

The general procedure is as follows:

FIELD WORK.

Copper nails with numbered tickets are driven into the timbers at the bottom of the manways of the cribbed passes, generally at a corner. The nails are connected to the survey of the level and their elevations determined. In the stope, any convenient pass is taken as a starting-point for the survey. A copper nail (numbered) is driven into the timbers in the same relative position as the nail below, and the distance between the nails measured. The passes can usually be treated as truly vertical without material error, but, if necessary, any deflection is easily determined by the use of a plumb-line or clinometer for inclination, and the compass for direction.

From this upper nail, stout twine, 100 ft. or more in length, is ranged round the stope, as a closed traverse, or to the reference nail in the next convenient pass. Supports for the string are provided by means of ordinary nails driven into the timbers, wedges driven into cracks in the rock, or long pegs driven into the day's drill-holes.

Supports are considered 'Stations,' and the lines are deflected as much as necessary to give the most effective positions. Between stations the lines are drawn taut, and care is taken that they foul nothing. The stations may be as close together as necessary, but should not be more than 25 ft. or 30 ft. apart, in order (*a*) to avoid excessive sag, and (*b*) to keep the effect of any error made in reading, whether due to carelessness or local attraction, at a minimum.

The compass is hung on the line at a convenient point, with the whole-circle zero ('North') forward in the direction of the traverse. The north-seeking end of the needle is read as a continuous bearing to a $\frac{1}{4}$°, when all steel, such as hammers, drills, shovels, picks, etc., has been removed to fully 20 ft. from the instrument. Steel-buckled belts are avoided, but it is found that the nails in mine boots cause no apparent deflection if the feet are kept vertically below the compass, or in line with the needle.

After removing the compass, the clinometer is hung at each end of the line in turn, about 18 in. from the supports, and both readings of inclination noted. There is a difference between the readings due to sag, varying with the tension of the string and the distance between stations.

Local cross-sections of the stope are then taken by means of the polar protractor. This instrument, though simple, is little used

by mine surveyors, and the modified form adopted warrants description:

A circular piece of 16 S.W.G. sheet brass, 8 in. diam., is marked on one side at every 5° from 0° to 360° in cyclic order. The first and fourth quadrants have the central portions removed, and from 180° to the centre a slit is cut which is just equal in width to the diam. of the string used (See Fig. 1).

The protractor is placed in position by passing the slit over the string, when it will hang in a vertical plane which is at right angles to the vertical plane of the traverse line, and the zero of the protractor will be vertically over the string at its centre. Any tendency of the protractor to slide along steep lines is easily counteracted by the compass clips.

The cross-sections are taken at every significant change in the shape of the stope. The protractor is hung on the line *so that the graduations face the observer, who looks in the direction of the traverse.* The ring of a linen tape is fastened by a spring hook to the end of a light extensible rod, and by means of the rod an assistant holds it, in turn, on the salient points in the cross-section desired. The tape is drawn taut and held in front of the protractor, just touching the string. The observer then reads the inclination and length of the offsett, keeping the tape in the correct plane by noting that it is parallel to the protractor. The offsetts are limited in length on account of (*a*) sag, (*b*) difficulty of adhering to cross-section plane, and (*c*) magnification of errors due to reading incorrect inclinations; and they should not ordinarily exceed 12 ft.

The distances of the cross-sections along the traverse line are noted, and for this purpose it is convenient to lay previously a special draft tape along the line, with its end fastened to the point of commencement.

The field-notes of a typical survey are appended. They need no explanation, with the exception of the cross-section notes. In these the encircled figure at the commencement of each line is the distance along the traverse line at which the particular section was taken; the figure before each bar is the inclination of the offsett, while the figure following the bar is the length of the offsett; thus: 120/5½ means that, at an inclination of 120° on the polar protractor, the offsett is 5½ ft.

Office Work.

In the office the inclined traverse lines are reduced to their horizontal and vertical components by the slide rule, using the mean vertical angle. The horizontal distances are determined to ¼ ft., and the vertical to 0·1 ft.

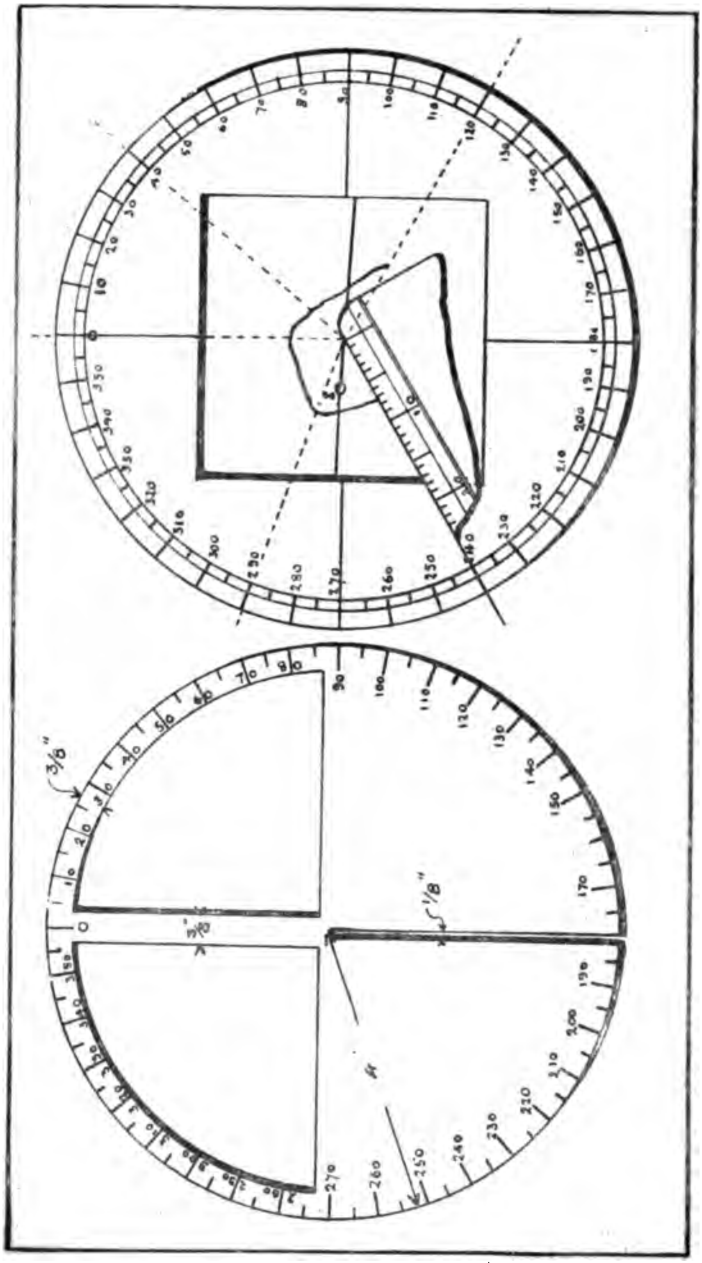


FIG. 1.

Cross-section Polar Protractor.
(Scale: $\frac{3}{8}$.)

Plotting Protractor.
Opening full-size: Circle reduced: Showing Cross-section plotted at 18 ft. on line G–I (Fig. 2).

Working from the predetermined elevation of the starting-point, ie elevation of each station is calculated, and if the survey has en closed on the origin or tied to other known points, one check ı the accuracy of the work is obtained. (Note Point D in Field-otes.)

The results of the three calculations (Horizontal and Vertical omponents and Elevations) are entered in specially reserved olumns in the field book. The work is completed graphically and o other calculations are made.

The graphic records are drawn to a scale of 1:250 on sheets f good quality blue tracing paper, cut to foolscap size, and filed ı ordinary end-opening folders, each folder being reserved for one tope. Co-ordinate lines are drawn on the sheets, and care is ıken that they occupy the same relative position on each sheet in ıy one folder. They will then register when bound and allow mparison of adjacent contours.

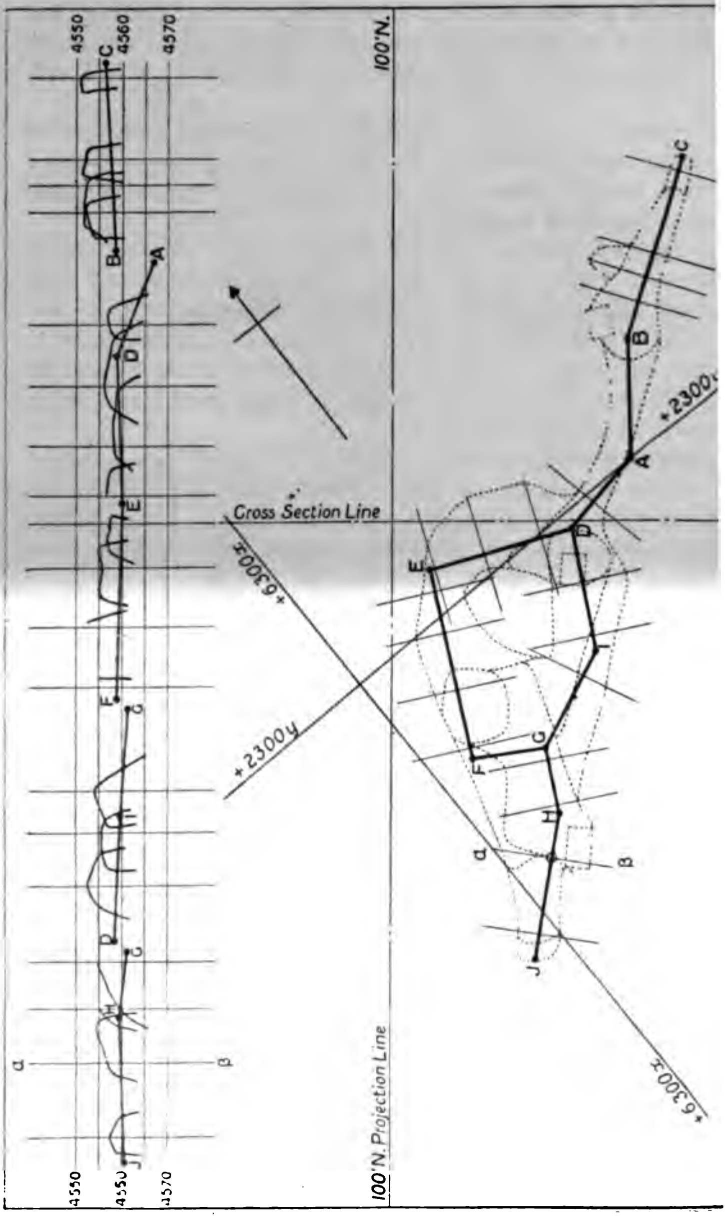
The known reference points are plotted or traced on one of the ıeets (to be known as the 'Key Plan') and from these the averse is plotted by protractor with the compass bearings cor-cted to true meridian; if the work has been properly done there ıould be no material difference in the closures.

The development of the traverse is plotted in elevation near the p of the same sheet, using the calculated elevations and hori-ıntal lengths, and working from a datum. Lines are drawn in loured inks (alternately red and yellow) parallel to the datum ıe, 5 ft. apart to scale, and numbered according to the elevations ıey represent.

The distances at which the polar protractor was placed are scaled ong the elevation of the traverse lines, and through these points ıort vertical lines are drawn. Short lines are also drawn at right ıgles to the travérse lines, through the projected positions of the ints on the plan. These operations give lines which are the aces of the planes on which cross-sections were taken.

In the elevation, the cross-sectional planes are rabatted on to the anes of the traverse lines, and the cross-sections are plotted in rrect relative position. This is done by means of a paper pro-actor, marked similarly to the polar protractor, with a $1\frac{1}{2}$ in. ıuare cut out of the centre. (Fig. 1.)

As an example:—In the plan of the traverse (Fig. 2), let a–β erpendicular to H–J represent the plan of the cross-section plane t 12 ft. along the line H–J, and in the elevations let the vertical ine a–β represent the elevation of the same plane. Let the plane ı–β be revolved (rabatted) in a cyclic direction through 90° about its


4550
4560
4570
100'N.
Cross Section Line
+6300x
+2300y
100'N. Projection Line
A
B
C
D
E
F
G
H
J
α
β

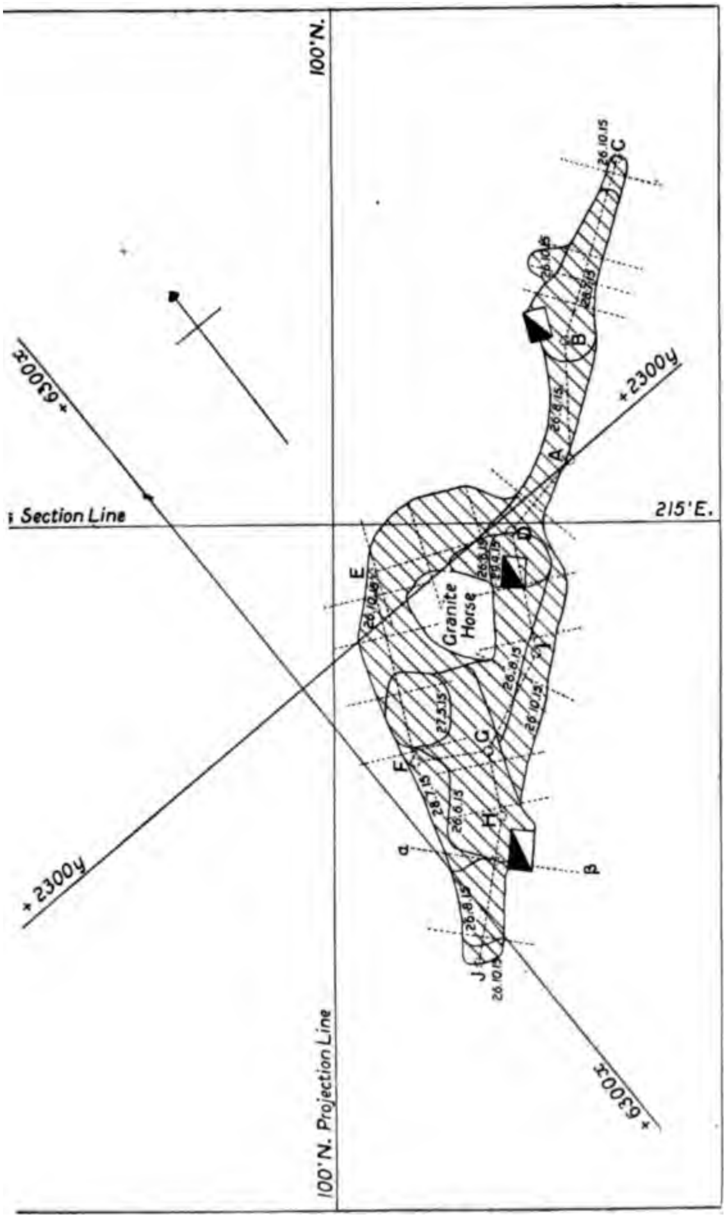


FIG. 3.— Stope 6-160, Contour 4560.

intersection, o, with the vertical plane through H–J, as an axis, when it will be coincident with the plane H–J, and, in elevation, with the plane of the paper. If the outline of the cross-section is now plotted it appears as shown around α–β in elevation, where the intersection of H–J and α–β represents the centre of the polar protractor and α–β the 0–180 axis.

The protractor is centred on the intersections of the vertical traces of the cross-sections with the elevation of the traverse lines, and the cross-section outlines directly plotted with a scale.

This completes the key plan on which the date of survey and names of party are noted.

Contours are plotted on individual sheets, and are taken at the 5 ft. intervals marked on the elevation of the traverse. The sheet of the contour to be plotted is fitted over the key plan with the aid of the co-ordinate lines, and the data on the lower sheet are read through the transparent paper.

NOTE: As the super-imposition of the contour sheet, Fig. 3, over the key plan, Fig. 2, would present considerable difficulty in the reproduction of Mr. Whyte's drawings, it has been thought desirable to indicate the effect of such super-imposition by showing the contour on the key plan, and *vice versa*, in dotted lines.

The distance from the vertical axis to the outline of any cross-section is measured with a pair of dividers along the line representing the elevation of the contour, and transferred to the line representing the trace of the cross-sectional plane on the plan.

This fixes one point on the contour, and the other points cut at that elevation are obtained by a repetition of the process. A free line drawn through the points represents the contour.

If the polar protractor has been used in the manner prescribed, it is known that measurements taken to the left of the vertical axes of the cross-sections must be plotted on the left-hand side of the traverse lines looking in the direction of the traverse and *vice versa*.

Difficulty is at first sometimes experienced in finding the correct lines to use and care is necessary, but remarkable dexterity is soon attained.

The completed sheets are filed in the covers in order, with the highest contour on top.

Accuracy and Limitations.

The only method, so far as the author is aware, comparable in accuracy with the one described, is that in which radial sights are taken, by means of a theodolite at a co-ordinated point, to salient

points around the open excavation, after which the calculated positions of the points are plotted and contours drawn by interpolation, but, as already explained, this method is not practicable in the filled stopes for which the polar protractor method was particularly devised.

In open stopes of considerable height and width, where comparatively long sights are possible, and where the whole working may be commanded from one or two settings of the instrument, the theodolite method is preferred, as the polar protractor and compass used as described are not economical in time. Between the two extremes are a variety of stopes where the method adopted is a matter of individual judgment, but it is noteworthy that wherever possible the compass-protractor method is used, and that the two methods are found to be interchangeable without difficulty.

Semi-permanent fixtures of iron, such as pipes and rails, interfere with the free use of the hanging compass, and where such are common in the stopes they render the method inapplicable.

An attempt is made to read the magnetic bearing of the traverse lines to $\frac{1}{4}^\circ$, but as the reading has frequently to be made by the bisection of the movement of a swinging needle, it is probable that errors of $\frac{1}{2}^\circ$ occur. On account of the short average length, and comparatively large number of traverse lines, and the short total length, the final error introduced by these differences is not great. In plan the traverses frequently close with no apparent error, and almost invariably within a foot to scale. In elevation the calculated closure is generally within 0·2 ft., and with special care it is not difficult to obtain an exact check.

Errors may occur when offsetting with the aid of the polar-protractor on account of (*a*) departure of the 0–180° axis from the vertical, (*b*) departure of the protractor from a plane perpendicular to the vertical plane of the traverse line, (*c*) increase in the sag of the string due to the weight of the protractor, (*d*) sag in the offsett tape. (*a*) and (*b*) are due to faulty construction, but a few experimental plottings will show that they have no serious effect up to a deflection of, say, 5°.

Small errors due to (*c*) are negligible, but when the total sag is equal to or more than 6 in., it is measured by noting the difference between the height of the string at the offsett point before and after the protractor is placed in position, and during plotting the centre of the protractor is displaced an equivalent amount. This error is only important on unusually long or slack lines, and could be reduced by using a protractor of lighter metal.

Sag in the offsett tape (*d*) causes the inclination shown by the

end of the tape at the protractor to differ from that of the straight line joining the end points. It is minimized by the use of a light tape with high tension, but is never entirely eliminated and must be kept small by a limit on the length of the offsetts. As previously stated, the offsetts do not ordinarily exceed 12 ft. which, even with an error of inclination as great as 5°, gives a displacement of only 1 ft.

Application.

The results of the survey are used for several purposes, among which are the following:

Vertical Projections.—Section lines are drawn at right angles to each other on the general plan of the mine, through the centre of the main shaft, to represent the planes of the vertical projections; one of the lines being parallel to the average strike.

Every key-plan and contour sheet has lines drawn parallel to these, with their distances from the original section lines noted.

The positions of the limits of the ore-shoot on the contour sheets are readily transferred to the vertical projection, with the aid of these lines and a pair of dividers.

A modification of this method is used in practice for the construction of the longitudinal projection. On a sheet of paper similar to the key-plan, corresponding cross-section and elevation lines are drawn. The section line of this sheet is fitted over that of the key-plan, and, by sliding the sheet to and fro, the elevation of the highest point of each of the local cross-sections is brought, in turn, over its position on the plan, and marked. The junction of the points thus obtained gives the projection. This method is more accurate than the one first described, as it takes account of work done above the elevation of the highest contour.

For the cross-section the contour sheets are used. In order to obtain this section relatively correct, a continuous line as irregular as necessary is drawn on the longitudinal projection to represent a plane, at right angles to that of the projection, along the centre of the ore-shoot. The intersections of this and the elevation lines are projected on the contour sheets and give lines along which the measurements are taken.

Estimation of Tonnage Broken.—The calculation of the volume excavated is made by using the ordinary prismoidal formula

$$V = \frac{h}{6}(a + b + 4m)^{*}$$

* V = volume. h = height. a and b = end areas. m = middle area.

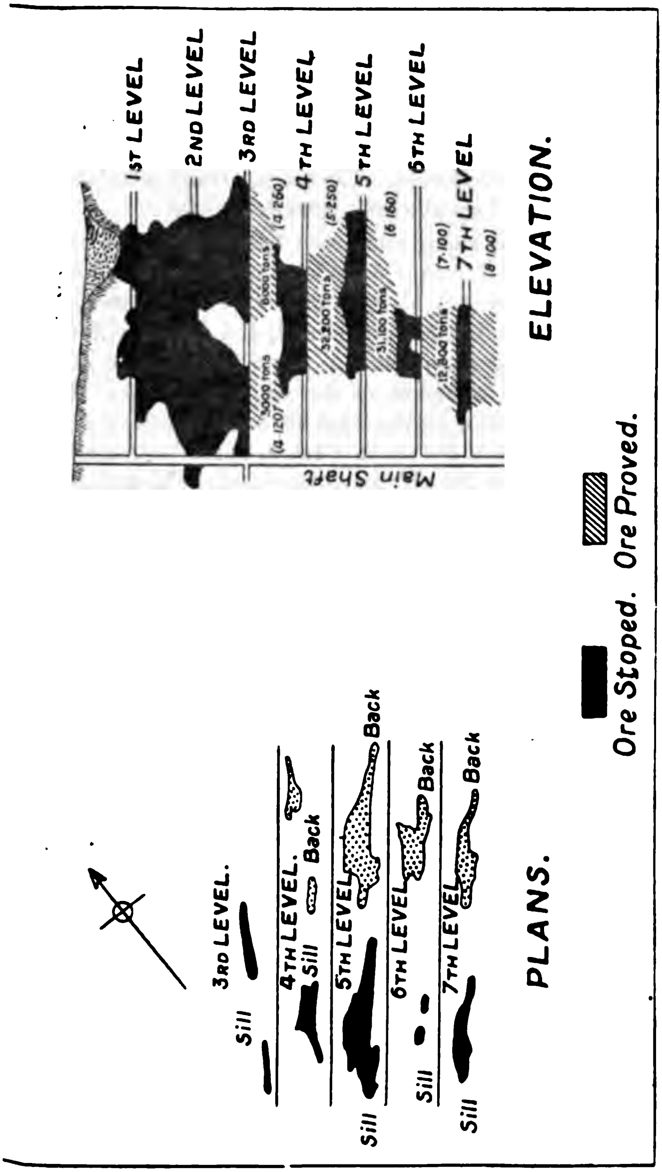


FIG. 4.—Messina Mine: Projection and Contours of portion of Bonanza Orebody illustrating irregular Cross-section and Ore Reserve calculation.

alternate contours being used to give the end areas of a series of prismoids, the height of which are twice the contour distances. The result, obtained as cubic feet of solid excavation, is converted to tonnage by a predetermined factor.

In the case of stopes where this method is used for contractors' measurement, it is necessary to make contours at 2 ft. intervals if the excavation is irregular and small.

Estimation of the Ore Reserve.—The ore reserve is calculated in the following manner where the ore occurs as a shoot:

The portion of the shoot remaining between the rail elevations of any two adjacent levels is considered as a block. The cross-sectional area of the sill of the upper level, corrected for any unprofitable ore which has been mined, and which will probably be avoided in stoping from below, is taken as the area of the top of the block. The contours of the stope below the block are examined, and the area of the highest contour which represents the full cross-section of the shoot is taken as the bottom area. The height of the block is the difference between the elevations of the end areas.

The ordinary prismoidal formula is of no service in calculating this volume, as the middle area is indeterminate, and the formula

$$V=\frac{h}{3}(a+b+\sqrt{ab})^{*}$$

is used. To determine the actual contents, the volume already stoped above the elevation taken as the lower end of the block is deducted from the result.

Ore is taken as 'proved' where both ends of the block are fully exposed, and there is reasonable evidence of continuity. This is generally provided by a winze through the centre of the ore-body, but local experience must always be a large factor in the classification.

* V = volume. h = height. a and b = end areas. m = middle area.

EXAMPLE OF ORE RESERVE CALCULATION.

BLOCK No. 5–260 BONANZA, 4TH TO 5TH LEVELS.

(*a*) Area 4th Level Sill, 2675 sq. ft. at elevation – 4410 ft.
(*b*) Area 5th Level Back, 7996 sq. ft. at elevation – 4488 ft.

$$h = (-4488) - (-4410) = 78 \text{ ft.} \quad \frac{h}{3} = 26 \text{ ft.}$$

		Log.
(a)	2,675	3·4273238
(b)	7,996	3·9028728
		2) 7·3301966
$\sqrt{ab}$	4,625	3·6650983
$(a+b+\sqrt{ab})$	15,296	4·1845779
$\frac{h}{3}$	26	1·4149733
(V)	397,696	5·5995512
Stoped above –4488 ft.	1,696	
Ore Reserve (cub. ft.)	396,000	5·5976952
Factor.............................	12·3	1·0899051
Ore Reserve (tons)	32,200	4·5077901

The average grade is determined volumetrically. The (sq. ft. × say) of each end of the block is treated as an end area in the ove formula, which now gives as V (cub. ft. × assay); from this sult the grade of the block is obtained.

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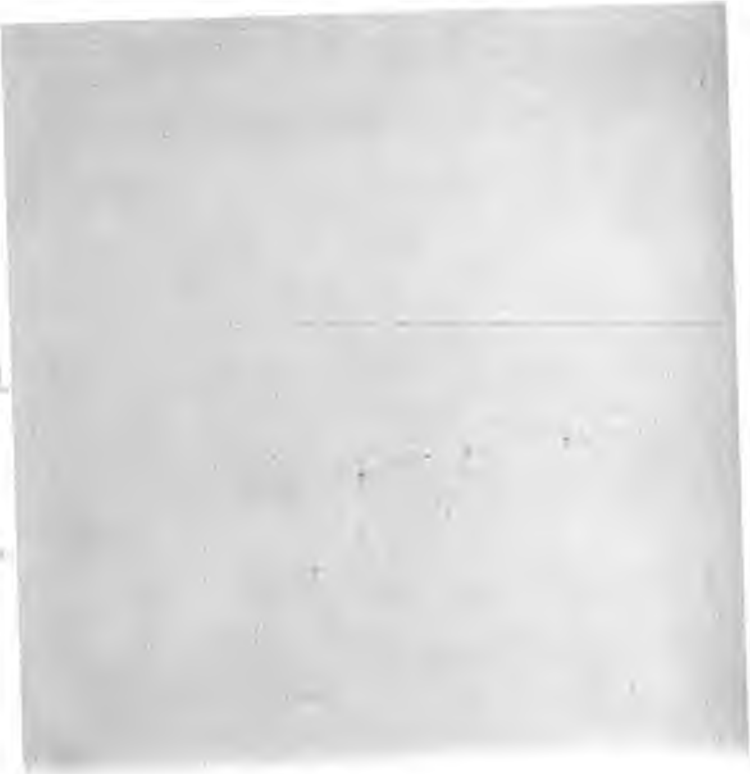
Offsetting with Polar Protractor.

A–B. String of traverse supporting protractor.
C–D. Draft tape.
E-F. Offsett tape fixed to rod held by Kaffir.



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A—

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[illegible]

Subject to revision.] [*A Paper to be discussed at a Meeting of the Institution of Mining and Metallurgy, to be held at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on Thursday, April 19th, 1917, at 5.30 o'clock p.m.*

Platinum in Spain.

By F. Gillman, *Member.*

Spain has long been noted for mineral wealth, especially in ores of mercury, silver, lead, zinc, copper, iron and sulphur, and three years ago we were startled by the discovery of potassic salts in the rock-salt district of Cardona (Catalonia), the deposits of which are being actively explored. Now the turn of platinum appears to have arrived.

In 1913, Don Domingo de Orueta, a mining engineer and member of council of the Spanish Geological Institute, during a field study of the peridotites in the Ronda highlands (province of Malaga) became impressed by the apparent analogy between these rocks (dunite, harzburgite, etc.) and those of the platiniferous district of the Urals, from which at least 90 % of the world's platinum is derived. After a laborious petrological examination of both Spanish and Russian rocks, for which more than 500 thin sections were prepared, Orueta found his surmise confirmed. He then provided himself with portable boring appliances, *bateas*, etc., imported a special 'rocker' from Russia, and proceeded to test the alluvial deposits and beds of the numerous rivers in the Ronda highlands.

His chosen field of operations was the huge mass of partly serpentinized peridotites which extends from near the Mediterranean at Estepona to the N.E. as far as Tolox, a distance of 25 miles, with a width of 8 to 10 miles, and which rises in several transverse chains or ridges to heights of 1000 to 1500 m. above sea-level. Having obtained from his numerous borings the necessary sand-samples, each of them weighing from 30 to 40 kg., he submitted their concentrates to spectral, microscopical and chemical analysis, and on October 30th, 1915, at a meeting of the Society of Civil Engineers at Madrid, he communicated his results. These may be recapitulated as follows:

(1) The majority of the samples proved to be platiniferous, the metal generally appearing in the form of minute, rounded or flat

grains, though sometimes as small, more or less water-worn nuggets, with a maximum weight of about 2 grm. It is associated chiefly with chromite.

(2) As in the Ural district, the platinum is concentrated in a stratum of sand 1 to 2 m. thick, resting on bedrock and covered by a practically barren overburden of varying depths from 8 to 12 m.

(3) Leaving out of count the samples of four borings which proved exceptionally rich, rather less than one-third of the borings yielded platinum at the rate of 2 to 3 grm. per cub. m.; more than a third contained 25 to 40 cgrm. per cub. m., while the remainder only contained a few microscopical grains of platinum, and may therefore be discarded as worthless. In this connection it is worth noting that, with the present price of platinum, alluvial ground containing only 20 to 25 cgrm. of platinum per cub. m. is profitably worked in the Ural district.

(4) As to the quality of the Malaga platinum, analysis proves it to contain from 78 to 82 % Pt, the remainder being the allied metals Pd, Rh, Ru, and Osmiridium; so that it does not differ essentially from the crude metal of other countries.

These satisfactory results pointed to the advisability of defining the extent and average possible yield of the platiniferous deposits, in order to determine whether they can be worked industrially. As this involves an expenditure beyond Señor Orueta's means (all previous work had been carried out at his expense), he sought Government aid, which was granted. The requisite mechanical drills and other equipment having been provided, Orueta, at the head of a competent staff, has again taken the field, to face two or three years more of diligent research. We can but wish him the success he deserves.

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MAY 17TH, 1917.

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LIST OF THE OFFICERS
OF
The Institution of Mining and Metallurgy
1917-1918.

The SIXTH GENERAL MEETING of the TWENTY-SIXTH SESSION of the Institution of Mining and Metallurgy will be held, by courtesy of the Council, at the Rooms of the Geological Society, Burlington House, Piccadilly, London, W., on THURSDAY, MAY 24TH, 1917, at **5.30** o'clock p.m.

The following Paper (copy of which is attached hereto) will be discussed :

Shall Great Britain and America adopt the Metric System ?

By WALTER RENTON INGALLS, *Member.*

(President, Mining and Metallurgical Society of America ; President, American Institute of Weights and Measures.)

The Council invite written contributions to the discussion of Papers from any members who may be unable to be present at the Meetings of the Institution.

Tea, Coffee and Light Refreshments will be provided at 5.0 p.m., for members and visitors attending the Meeting.

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the qualifications of Candidates for Admission into the Institution fulfil the requirements of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be open for inspection at the Office of the Institution for a period of at least two months from the date of the Bulletin in which their applications are announced.

The following have applied for admission since April 12th, 1917:—

To Membership—

Caddick, Arthur James (*Rio Tinto, Spain*).
Key, John Frederick (*Broken Hill, New South Wales*).
Scott, Frederick Bowes (*Salmon Arm, British Columbia*).

To Associateship—

Graham, Harry Woodthorpe (*B.E.F.*).
Lamb, Cyril Leonard (*Nigel, Transvaal*).
Lawn, Herbert (*Dalton-in-Furness, Lancashire*).
Soar, Vincent Douglas (*B.E.F.*).
Wilson, Archibald Woodville (*Mount Morgan, Queensland*).

To Studentship—

Dempster, Ian Mackay (*Camborne, Cornwall*).
Griffith, Stanley Vincent (*Camborne, Cornwall*).
Ranger, John Osborn (*B.E.F.*).
Waddell, James Robert (*London*).
Yipp, George Wing (*Camborne, Cornwall*).

The following have applied for Transfer:—

To Associateship—

Bruce, Albert Edwin (*La Paz, Bolivia*).
Jones, Edward Oswald (*B.E.F.*).
Plummer, Benjamin Douglas (*B.E.F.*).
Richards, James Foster (*B.E.F.*).
Sellers, William George (*London*).

NEW MEMBERS.

The following have been elected (subject to compliance with the conditions of the By-Laws) since April 12th, 1917:—

To Membership—

Gillio, Joseph John (*Congo Belge*).
Saunders, Thomas Skewes (*El Oro, Mexico*).

To Associateship—

Frazee, Verne (*Holkol, Korea*).
Mack, Augustus Charles (*Kotchkar, Russia*).
Moore, Karl Byron (*Youanme, Western Australia*).
Thomson, Robert (*B.E.F.*).
Thomas, Joshua (*Tavoy, Lower Burma*).

NEW MEMBERS—*continued.*

To Studentship—

Curnow, Thomas John (*Penzance, Cornwall*).
Dempster, Eric Richard (*Morriston, South India*).
Grut, Leslie de Jersey (*B.E.F.*).
Mosditchian, Hrand Sarkis (*London*).
Pryor, Edward James (*London*).
Rees, Leslie Charles (*Swansea, Glamorganshire*).
Toll, Reginald Warmington (*Bere Alston, Devonshire*).

The following has been transferred:—

To Associateship—

Guttentag, Wilfred Emil (*London*).

MOVEMENTS OF MEMBERS.

Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. T. Buxton, Assoc. Inst. M.M., has returned to England from the Congo Belge.

Mr. J. Descraques, Assoc. Inst. M.M., is returning to England from the Federated Malay States.

Mr. S. H. Eu, Assoc. Inst. M.M., has been appointed Manager of the Kadaik Mining Syndicate, Zingyaik, Burma, but his address is still at Kuala Lumpor, Federated Malay States.

Mr. W. Frank Lander, Stud. Inst. M.M., is returning to England from Northern Nigeria.

Mr. Frank C. Laurie, Assoc. Inst. M.M., has been appointed General Superintendent in charge of the Mexican operations of the Freeport & Tampico Oil Corporation, with headquarters at Tampico.

Mr. A. Trevor Roberts, Assoc. Inst. M.M., has returned to England from Northern Nigeria, on leave until the end of June.

Mr. C. Salter, A.R.S.M., Assoc. Inst. M.M., having failed to pass the medical examination for the Army, left the service of the Government of the Federated Malay States (Geological Department) to join the staff of the Straits Trading Co., Ltd., at Singapore.

Mr. Ernest R. Woakes, M. Inst. M.M., has returned to England from a visit to the Argentine Republic and Brazil.

Mr. W. R. Wright, Assoc. Inst. M.M., has returned to England from Nigeria.

ADDRESSES LOST.

F. B. Bradshaw, O. L. de Lissa, and D. Nicholas.

INDEX OF RECENT BOOKS.

NOTE.—Books marked with an asterisk are contained in the Library of the Institution.

*CALIFORNIA STATE MINING BUREAU: FIRST ANNUAL REPORT OF THE STATE OIL AND GAS SUPERVISOR FOR THE YEAR 1915-1916. San Francisco: California State Mining Bureau.

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Flotation of Gold Ores. F. A. Beauchamp. —Mining and Scientific Press, San Francisco, Vol. 114, March 10, 1917, pp. 325-6. 15*c.*

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MILITARY SERVICE.

SUPPLEMENTARY LIST.

The following have been notified since the issue of the last Bulletin, April 12th, 1917:

MEMBERS SERVING WITH H.M. FORCES.

CORBIN, H. BURTON, (2nd Lieut.).
DANIELS, IVOR C., Royal Engineers, (2nd Lieut.).
EDGAR, H. SWAN, Gordon Highlanders (Canadian Forces), (Lieut.).
GIBB, J. A. P., Royal Engineers, (2nd Lieut.).
GRIMLEY, P., General Service, (2nd Lieut.).
GRIST, H. N., Royal Engineers, (2nd Lieut.).
GRUT, L. DE JERSEY, Australian Engineers, (Captain).
HAWKES, W. B., Malay States Volunteer Rifles.
HAWORTH, ABRAHAM. (*No particulars.*)
LAKELAND, W. J., Indian Army Reserve of Officers, (Lieut.).
RICHARDS, J. FOSTER, Royal Engineers, (2nd Lieut.)
RUNDLE, R. H., South African Forces, (Sapper).
SPARGO, ARTHUR, Egyptian Labour Corps, (2nd Lieut.).
THOMSON, ROBERT, Royal Engineers, (2nd Lieut.).

PROMOTIONS OR OTHER CHANGES.

COWLAND, A., Royal Engineers, (Lieut.).
GILL, DONALD, Royal Garrison Artillery, (Captain).
HENKEL, W. E. G., Middlesex Regiment, (Captain).
HOWARTH, H. S., Sappers and Miners, (2nd Lieut., Indian Army Reserve of Officers).
JONES, E. O., Royal Engineers, (Lieut.).
KINAHAN, B. A. D., Royal Engineers, (Captain).
MCCALLUM, N. S. K., Royal Engineers, (2nd Lieut.).
MCEVOY, JAMES, Canadian Engineers, (Major).
MACLACHLAN, D. K. F., Royal Engineers, (Captain).
NEWELL, E. F., (*Transferred to Army Reserve*).
PARKER, A. E., Royal Engineers, (Lieut.).
PLUMMER, D. B., Royal Engineers, (Captain).
SAWYER, R. E., South African Forces, (Lieut.).
THRUPP, G. A., Sikh Pioneers, (Lieut., Indian Army Reserve of Officers).
WEEKS, W. G., Royal Engineers, (Captain).

CROWTHER & GOODMAN, LTD., Printers, 124, Fenchurch Street. London, E.C. 3.

TWENTY-SIXTH SESSION, 1916-1917.

TWENTY-SIXTH ANNUAL GENERAL MEETING, Thursday, April 19th, 1917.

Held at the Rooms of the Geological Society, Burlington House, Piccadilly, W. 1.

MR. EDGAR TAYLOR (*President*) in the Chair.

The minutes of the Twenty-fifth Annual General Meeting, held on Thursday, March 23rd, 1916, were read and confirmed.

The President said that before proceeding to the ordinary business the members would, he felt sure, expect him to refer in a few words to the inspiring developments of the past week or two in connection with the great world upheaval which was dominating all their thoughts and actions in these anxious times. The first in point of time of the two outstanding political events was, of course, the Revolution in Russia, which had changed by one stroke, as they all hoped and believed only for good, the whole future of that mighty Empire. No doubt there were internal difficulties yet to be overcome in Russia, but he thought they were justified in believing that, by the wise moderation and forbearance of the leaders of the Russian people, of which they had seen so many evidences, the full fruits of the comparatively bloodless Revolution would be secured, and that it might prove to be the beginning of a new era of progress and prosperity, and the final overthrow in Russia of the evil influences from which the Allied Nations had all suffered in varying degrees for so long.

The other great event to which he referred was the advent of the American Nation into the War. It was an event which would stand out in history for all time. Great as its material effect would be, its moral effect would be infinitely greater, and they all rejoiced to have their American friends fighting side by side with them in this terrible struggle.

It was a glorious fact that the Union Jack and the Stars and Stripes were uniting the whole English-speaking world with the Allied European Nations in this great fight for freedom and civilisation. The subject was too great for him to attem-

it, so with that brief reference he would submit to the members a message of greeting which he felt sure they would desire should be sent to their Sister Society, the American Institute of Mining Engineers:—

'The Institution of Mining and Metallurgy, assembled in London in Annual General Meeting, sends fraternal greetings to the American Institute of Mining Engineers, and rejoices in the new bond of friendship and unity of purpose between the two Societies resulting from the great historic act of participation of the American people in the War of Freedom and Civilization against Military Autocracy and Barbarity.'

Sir Thomas Kirke Rose said he was most heartily in accord with the resolution, and it gave him great pleasure to second it.

The resolution was carried by acclamation.

The President stated that the message would be cabled on the following day to New York.

NOTE:—The following reply was subsequently received by cable:

'Your cordial greetings much appreciated by American Institute of Mining Engineers, whose Board of Directors at its meeting last evening responded with sincere wishes and statement that the members of our Body are doing all in their power to hasten active participation with our Allies. Philip N. Moore, President; Bradley Stoughton, Secretary.'

Mr. William Habakkuk said he had much pleasure in moving: 'That Messrs. C. J. Price, H. Brelick and S. J. Lett be and are hereby appointed Scrutineers to examine the balloting papers for the election of Members of Council.'

Mr. W. R. Thomas seconded the resolution, which was carried unanimously.

The Secretary then read an abstract of the Report.*

The President said that in connection with the Committee of the Privy Council for Scientific and Industrial Research, he had only that day received a letter from Dr. Heath asking him to continue in office for a further twelve months, viz., until March, 1918, and desiring him to ask the same gentlemen to continue to act till then.

The Report which had just been read spoke for itself, and he felt sure the members would agree with him that in all the circumstances the position of the Institution at the end of 1916, after two and a half years of war, was eminently satisfactory. He need not do more than refer in a few words to one or two points.

He was glad to be able to say that the Tin and Tungsten Research was making very satisfactory progress under the direction of Sir Thomas Rose's Committee, and he thought the Council were

* The Report of Council and Statement of Accounts were issued with the April *Bulletin*.

thoroughly justified in looking for solid results from the investigation. A very large amount of work had been done, but much more still remained to be done; in fact, there could not be any absolute finality in work of that character.

With regard to the proposal for the organization of the mineral and metal industries of the Empire, he understood that no decision had yet been come to by the Government, so far as the machinery for giving effect to the proposal was concerned, but the principle had met with complete approval. The question of the organized development of their mineral resources not only affected the whole Empire but was bound up with their future relations with the Allied Nations, and it was one which required the most serious consideration of the Imperial Government, which he had good reason to believe it was actually receiving. He hoped that a decision would be arrived at without unnecessary delay.

Meanwhile, a beginning had been made in regard to the mineral resources of the British Isles, so far as they were affected by War requirements, by a Department of the Ministry of Munitions, of which their friend, Sir Lionel Phillips, was the head. He (the President) and several of his fellow-members of the Institution were serving on Sir Lionel Phillips' Advisory Committee, and they were of course giving all the assistance in their power. The fact that at this late date in the War such a Department had to be hastily set up was an additional proof, if any were needed, of the necessity for a Department of Minerals and Metals, the establishment of which they, with the support of the Institutions representing the other branches of the mineral and metal industries, had strongly urged upon the Imperial Government.

It was a gratifying fact that the Governments of most of the Dominions had already definitely approved the proposal, and it had also been approved in principle by the Dominions Royal Commission, who, in their extremely instructive and constructive Final Report just issued, laid special stress upon the urgency of the work to be done.

With regard to the taxation of the Mining Industry, he felt that the Institution was right in devoting its energies to that difficult and most important question, with the object of securing in the first place an equitable adjustment of the incidence of the Excess Profits Duty, and secondly of the Income Tax.

The members were all aware of the conditions of risk and uncertainty which made the Mining Industry differ so essentially from other industrial enterprises, and anything which threatened the industry, as those anomalies of taxation did, was of serious moment

to the national interests. He relied, however, with confidence upon the united efforts of the Institution and the Companies affected proving successful in securing an equitable adjustment of the question.

With those very brief remarks he begged to move that the Report and Accounts be adopted.

Mr. E. W. Janson had great pleasure in seconding the adoption of the Report and Accounts. There was only one remark he would like to make. Whatever the War had done for them in a detrimental way, it had certainly largely increased the activities of the Institution, and he thought it was a matter of great benefit to the country that the Institution had taken action on so many questions affecting the industries of mining and metallurgy.

The Report and Statement of Accounts were unanimously adopted.

The President was sure that the next resolution which he had to move required no words of his to recommend it. They had enjoyed the hospitality of those Rooms for their General Meetings for so many years that they had almost become their second home. He begged to move:

'That the thanks of the Institution of Mining and Metallurgy be, and are hereby accorded to the Council of the Geological Society for their courtesy in again granting the use of their Rooms for the Institution Meetings during the present Session.'

Dr. J. A. L. Henderson seconded the resolution, which was carried unanimously.

Mr. Sydney W. Smith said that his pleasure in proposing a resolution of thanks to the President, Council and Officers of the Institution for their services during the past year was only tempered by a sense of responsibility in attempting to give adequate expression of the Institution's indebtedness to them. It would be a matter of great satisfaction to everyone to learn that Mr. Edgar Taylor would preside over them for another term. He need hardly speak of the esteem, he might almost say the affection, with which Mr. Taylor was regarded in the Institution. The dignity and the courtesy which he invariably brought to their Proceedings made it doubly fortunate and gratifying that his ripe experience and mature judgment should be at the disposal of the Institution for another term.

With regard to the work of the Council during the past year, he need not refer to details: they were before the members in the Report of the Council, of which an abstract had been read by the Secretary. After the welter of the present strife it was certain that

those who accepted the immense responsibilities of controlling and directing the destinies of this country would look with expectation and confidence to the Council of the Institution for guidance and assistance in relation to those matters with which it was more immediately concerned.

Having regard to the past records and to the present virility of the Council, he thought there was abundant promise that that expectation and that confidence would not be misplaced. It was a matter of the greatest satisfaction during these times, when almost everyone's energies were directed to action rather than to reflection, that the Council of the Institution, and the Councils of other bodies, should be able to formulate, with steadiness and with their collective wisdom, plans for the reconstruction in the future. They welcomed the lead which the Institution had taken, not only in reflecting the best practice in the arts which it professionally represented, but also in the steps which it was taking to ensure that sound principles were promulgated on which the best practice alone could be based.

There was one paragraph in the Council's Report, an unavoidable paragraph, which he was sure they all hoped might never appear there again: he referred to the fact that the post-graduate Scholarships and other Awards were in abeyance. In the past they had followed with great interest the sustained and widening policy of the Institution in exerting its influence, and making its influence effective, in matters relating to the training and guidance of those who, in a few brief years, would be responsible for giving effect to those aspirations of well-being in the industries which they represented, aspirations which at this time more than at any previous time they were all so anxious to see realized.

They were all greatly concerned at the present time about the co-ordination of information and the efficient development of their resources, but, after all, their greatest resources were those who were entering upon a great inheritance. Bringing with them, as one hoped, the very best intentions to excel, they would still need abundant facilities and proper guidance to enable them to show themselves worthy of the great sacrifices which were being made for their very existence as an unfettered nation.

With regard to the work of the Officers of the Institution, he thought they were all familiar with the wealth of metaphor which had been applied in the past to the good qualities of their Secretary. Enthusiasm had, at times, reached such heights that metaphor had been poured out with a reckless disregard of the consequences of mixing good things. He found that one speaker had referred

almost in the same breath to their Secretary as 'a steady helmsman,' and also as 'a sturdy Eddystone above the ebb and flow.' No doubt the speaker on that occasion was anxious to express what they all felt, that their Secretary's functions were so many and so various that, whether in taking a turn at the tiller or whether in shedding light and guidance over the uncharted wastes, he was always rendering invaluable services to the Institution.

It was with great pleasure and with great confidence of a generous response that he moved the following resolution:

'That the Members of the Institution of Mining and Metallurgy note with satisfaction that the activities of the Institution during 1916 were fully maintained, and that its financial position after two and a half years of War suffered to so small an extent as that shown by the Accounts, and they desired to record their sense of appreciation and thanks to the President, Council and Officers for the important work accomplished by the Institution during the year to which the Council's Report bears evidence.'

Mr. R. O. H. Spence said it was with great pleasure that he seconded the resolution just moved, which had been so well put to the meeting by Mr. Sydney W. Smith. Mr. Smith had left little for him to add. When asked to undertake the task he had felt honoured at being paid that compliment; he felt more honoured and proud now that he was actually performing that pleasing duty. As an Associate of the Institution whose official duties compelled him to reside in a somewhat distant corner of the far-flung British Empire, namely, British Guiana, he could testify to the pleasure which the papers and the *Transactions* of the Institution brought to the members and associates abroad, and to the interest with which they were read, and the instruction and up-to-date information derived therefrom.

His personal experiences of the Council and their Secretary and the whole staff, on the occasions that he had been in England, had always been of the happiest. He had had the honour of being present at the last annual dinner given by the Institution in April, 1914, when one who, alas! was no longer with them to-day, was the President. His speech, which was on record in the *Transactions* of the Institution, stood as an everlasting proof—if such were needed—of the man's sterling ability and worth. It would be presumption on his part to say more about the late Mr. Bedford McNeill whom, he was pleased to say, he had got to know personally in March, 1914, and the news of whose death had come as a great shock to him, as he felt sure it had to every member, associate and student of the Institution. At that same last annual dinner, by a lucky chance, he had got to know other worthy members of the

Institution and Council, from whom he had received great personal kindness and invaluable help.

With regard to the Secretary, he could only say that he looked upon him as a friend. He owed him several debts of personal and official gratitude. If the opportunity ever arose, he would have the greatest satisfaction and pleasure in trying to return them in some small way.

As to the rest of the staff, he would add that it gave him the greatest satisfaction and pleasure to express his appreciation, and might he say the appreciation and thanks of the whole membership of the Institution, for the efficient way in which they had performed their duties in the trying time through which they had passed and were still passing.

The resolution was carried unanimously.

The President desired, on behalf of his brother members on the Council, and of the Secretary and staff, to thank Mr. Sydney Smith and Mr. Spence very much indeed for the kind way in which they had put the resolution before the meeting. To him it was a perfect marvel to note the way in which the Council had devoted their time to the work of the Institution. If he were to let the members into the secrets of the attendance book of the Council, he felt sure they would be, not surprised, but more than delighted to see what careful attention their elected Council year by year gave to the work of the Institution.

For their kindly remarks in regard to the Secretary he returned thanks warmly on his behalf. He was so constantly in touch with the Secretary in the work of the Institution that he perhaps, as well as anybody, knew how devoted he was to his work, and to the good of the Institution. The staff of the House in Finsbury Circus, who worked under Mr. McDermid, he also knew, and he endorsed every word that had been said as to the manner in which their work had been carried out.

As to himself, he was in their hands. He could only assure them that it had been his desire throughout that any power, any knowledge, or any work that there was in him, which he could use for the good of the Institution, should continue to be exercised during the term for which they had been so good as to re-appoint him, namely, until March next year.

Mr. William Dewar moved: 'That Messrs. Woodthorpe, Bevan & Co., Chartered Accountants, be and are hereby re-appointed Auditors of the Institution accounts for the current year.'

Mr. Alexander Richardson seconded the motion, which was carried unanimously.

The President pointed out that in ordinary circumstances they would have had an opportunity at that meeting of thanking the retiring President in person for his conduct in the Chair during the preceding year. As they were aware, Sir Richard Redmayne had found it necessary in August last to relinquish the Presidency, but he felt sure they would wish to record their cordial thanks to him for his services to the Institution during the months of his occupancy of the Chair. As many of them knew, Sir Richard Redmayne was now occupying a very onerous position in the Government in connection with the coal industry, and he was sure that Sir Richard had their good wishes in a special sense in the discharge of his very responsible duties. He therefore asked them to record their thanks to him for his conduct in the Presidential Chair.

Mr. Walter McDermott said he had great pleasure in seconding the resolution. They all recognized that Sir Richard Redmayne, as far as he was able to devote his time to the Institution, had made an excellent President, and they owed him as much thanks for what he had been able to do as if he had served his full term as he had intended to do. The loss of his services had been softened to them by the success of the Council in dragging Mr. Edgar Taylor again to the Chair, forcing him into it, and not only forcing him into it, but making him take an additional term when they got him there.

The resolution was carried by acclamation.

The President said he had now rather a curious duty to perform. In the ordinary course he would have to rise and deliver a Presidential Address. He would relieve their minds at once by saying he had no such intention.

All he had to do was to get out of the Chair and get in again. If he were permitted, he would do so by sitting down.

At the conclusion of the meeting the Scrutineers reported that the following were elected Members of Council: Messrs. R. Gilman Brown, John Cadman, H. C. H. Carpenter, T. C. Cloud, R. E. Commans, Arthur Dickinson, W. R. Feldtmann, *Sir* Robert A. Hadfield, Dr. J. A. L. Henderson, *Sir* Thomas Henry Holland, Messrs. E. W. Janson, Hugh F. Marriott, J. C. Moulden, Reginald Pawle, Arthur E. Pettit, Hugh K. Picard, S. J. Speak, Charles F. Stewart, R. Arthur Thomas, W. H. Trewartha-James, S. J. Truscott, Leslie Urquhart, Stephen Vivian, W. Fischer Wilkinson and Ernest R. Woakes.

The President moved, and **Mr. Humphrey Morgan** seconded, a hearty vote of thanks to the Scrutineers, which was carried by acclamation.

DISCUSSION

ON

'Stope Measurement at Messina.'

By WILLIAM WHYTE, *Associate.*

:. Humphrey M. Morgans, after briefly describing the
›r's method, said that the system appeared to have been
mely well worked out. There must be some practice needed
der to get consistent and accurate results, but he thought,
that practice and the care that was necessary so as to get the
ngs correct, it must lead to a very accurate knowledge of the
ıge which each stope yielded.

r. Morgans then read Mr. L. H. Cooke's written contribu-
o the discussion.

r. L. H. Cooke: The special method of stope-surveying so
y described in great detail by Mr. Whyte should be welcomed,
adds another resource to the mine-surveyor faced by difficulties
ke nature. Broadly characterized, the method is a combination
e use of the old but evergreen *hängezeug* with a novel and
ble variant of the 'Sunflower' cross-sectioner first used in
ew Croton Aqueduct some thirty or forty years ago.

tle adverse criticism seems possible as regards the main
rse made with the old *hängezeug* on time-honoured lines, but
e or two respects the author is a little more exacting than is
for such small branch-surveys: as instances, the limit of the
h of the drafts, viz., 'not more than 25 ft. or 30 ft.' and the
val of steel tools 20 ft. or more away from the instrument seem
r rigorous requirements for this class of work.

regards the 25 ft. to 30 ft. maximum draft, in the example given
pical by the author, there are no less than four drafts out of
hose lengths each exceed 30 ft., and two of them are 40 ft. or
rds in length. There must be occasions when still longer
ı are convenient or essential, e.g., to enable the compass to be
at a sufficient distance from iron and steel objects which it is
esirable to remove. It is true that the Continental mine-
yors often limit their drafts to 10 m. (32·8 ft.) when accurate
ed levels are required; but this is for best work, not for stope-
ying.

ısibly, however, the 'excessive sag' of longer drafts mentioned
r. Whyte (p. 2) is not so objectionable on account of resultant
ı in elevation (seeing that a local variation of 6 in. for a whole
ıal section is permitted as stated on p. 9) as on account of the

compass drooping to the floor, footwall, or broken stuff in vertically narrow openings, when it may take an incorrect position and demand a further expenditure of time on a re-adjustment of the cord, or a change of station, etc. This can usually be avoided by testing the tension by pressing down the cord, but I would not willingly let slip the opportunity of suggesting to instrument-makers that now is the time to consider the introduction of a somewhat smaller and lighter compass specially designed for stope-surveying.

The supporting frame in which the compass swings could be advantageously made of aluminium or magnalium, and its leading edge or 'north' prow could be waved to distinguish it as suggested by Professor Haussmann. Such a lighter tool would demand less care as to sag.

If the 'excessive sag,' which causes the author to avoid drafts longer than 25 ft. or 30 ft., is experienced with the cross-sectioner, then the use of a lighter metal for it such as aluminium or magnalium would certainly seem desirable.

If, lastly, the 'excessive sag' is feared on account of its effect on the main clinometer readings, then one would have thought that the old practice of reading the main clinometer before the compass has been applied, and has stretched and slackened the cord, would have been adopted.

Also, as the clinometer is used twice on each draft, might it not be turned end for end, for the second observation, with advantage as regards the partial compensation of some of its errors of construction? I do not quite grasp the degree of accuracy as regards elevation at which the author is aiming, but suggest that possibly hanging the clinometer only once and at the middle of the draft or, on steeper lines, a little above the middle would be quicker and perhaps as satisfactory.

Whatever may be the explanation of the author's objection to long lines on account of excessive sag, it is obvious that longer drafts would often be convenient and would often expedite the work. The experiment of increasing the maximum length of draft seems worth a trial.

It is my impression, based on a good deal of miscellaneous compass surveying, that unless there is a very considerable pile of steel tools, the minimum of 20 ft. for their distance from the compass can be much reduced. Having only just received the paper, I have not yet had time to obtain more than one numerical illustration for present use. At different points along a cord stretched for 36 ft. I read several bearings with a Freiberg com-

pass having an excellent needle. Three poll-picks, whose heads with wedges must weigh 10 or 12 lb., were piled with their heads close to one 'station' or end of the cord. No perceptible difference of reading was obtained till the compass was only a yard and a half from the pickheads.

The avoidance of belts with steel buckles is very necessary, as the author states, and it may be well to add for the benefit of the young surveyor not familiar with compass work, that nearly all that glitters like brass is not solid metal but merely coats a core of steel. It may, perhaps, not be out of place to recall to mind that a magnetic substance influences the needle inversely as the square of its distance from it. Consequently it is advisable that any metal object worn on the upper part of the person should be tested as to its effect on the needle.

Again, if ordinary nails are used to hold the cord at the angular points or 'stations' of the traverse, a practice commonly permissible, there will be points where it will be better to use brass screws, preferably those sold with metal handles or keys to facilitate their insertion or withdrawal. At times it is advantageous to hang the compass close to the station, as, for example, in a case where otherwise the sag would be so great as to lower the compass on the rock, etc.

The cross-sectioner strikes one as a handy tool, but only experience with it can make one fully appreciate its merits and realize its drawbacks. Of the latter, the following occur to me: (*a*) extra sag of the traverse-draft already dealt with, (*b*) coarse and inaccurate reading owing to the disadvantageous position of the tape used as index. Whether these drawbacks are sufficiently great to lead one to prefer the method practised by Mr. F. T. Greene (I am in Cornwall and unable to give reference at present), of hanging the offsetting clinometer on the tape itself and not on the draft-cord, only a practical comparison can decide. Such a practical comparison should also include the use of the theodolite as described for the shrinkage-stopes of Mount Lyell and North Mount Lyell Mines in the *Transactions* of the Australasian Institute of Mining Engineers. In this method, vertical sections are taken by the theodolite in various planes radiating from the azimuth-axis of the instrument, a method not clearly specified by Mr. Whyte as having been under his consideration.

The estimates of ore broken and in reserve are made by the author with the standard formulæ—methods which I have taught as standards of comparison for nearly 30 years; the formula used for the ore-reserve example is a special case of the prismoidal

formula. It need not be used when the parallel end-areas are not very unequal. Even when the ratio of one to the other is as much as 1 : 9, as in the numerical example in the paper, the difference between the standard value and the rougher approximation obtained by using the arithmetic mean of the two areas is only some 4 or 5 %.

Seven-place logarithms are out of place for such calculations. They will give an accuracy of 1 in 1,000,000 or higher, if the data are correspondingly trustworthy, but here the data used are often incorrect from 1 in 400 to 1 in 40, and the use of the formula implies a guess as to the value of the ore remaining constant. Good four-place tables would serve the purpose, and the handy five-place tables would give an ample margin of accuracy and would perhaps be most convenient.

Not only would the reduction in the amount of computation and chances of blunders increase the speed, but the smaller size of the tables, the fewer pages to turn over, fewer numerals to take out and transcribe, would tend to the same end. In short, the fewer the figures the fewer the blunders and the faster the progress.

Mr. H. F. Marriott said that the mention of the hanging compass took him back to his earliest days of mining in Spain when a comrade and he were instructed to survey a lead mine, which had difficulties commensurate with those before them, and they were provided for this purpose with a hanging compass and pegs and line. They made serious and enthusiastic efforts to get some sort of result out of the compass. There was a good deal of iron about in the mine, some not removable, which affected the compass, and the instability of the support made this influence variable and rendered the readings useless. Finally, they had to depend upon a prismatic compass and an Abney level, and he found that after running over the work three times they got as good results as they desired.

With regard to the use of the needle, he did not see why any one would take the risk of using a compass under ground, however accurately the needle might work, except simply as a fixed needle, that was to say, always reading the back-sight and fore-sight. In the case of the hanging compass a slight slackening or tightening of the line might bring the compass into a different position with regard to iron in the vicinity, and produce an erroneous reading.

In later work in the Transvaal, he remembered having to survey a mine which had not been entered for several years, and which had many places in it only large enough to crawl through. It was a horizontal lode and therefore probably as difficult as the vertical

vein referred to in the paper. He obtained the necessary accuracy with a small theodolite set up on a candle box instead of on its usual supports. He should say that with either a 3-in. theodolite or the combination of prismatic compass and Abney level, surveyors would find they could determine any difficult position that was accessible to themselves with more accuracy than by any other method.

Mr. Humphrey Morgans said that the effect of iron or steel on a loose needle survey was less than was generally thought. A loose needle survey of a mine with the rails in position would give as good results as if the rails were removed by taking the precaution of getting the needle about as far from one rail as it was from the other. Of course, if there was a mass of magnetic material in the wall or anything of that kind the loose needle survey would not be accurate.

Mr. H. A. Titcomb wished to make one remark about the attraction on the needle. He was not a special surveyor, but had had to do a considerable amount of such work in connection with ore-estimates, and he found in such stopes as those described that the Brunton pocket transit was a useful instrument. It gave the vertical angles as well as the compass reading. With regard to local attraction, of course it was well known that if one could use an ordinary compass, that was an ordinary needle, and take back and front-sights, one would come to places where one would get an agreement between the back and the front-sights at two or more consecutive stations, which indicated that at those points there was no local attraction; and from those correct bearings it was easy to correct the others. But he did not see how that could be done in the case of a compass suspended from a string. He did not see how one could get a back-sight in that case, as the compass would not be located exactly at the station.

The President invited further discussion by correspondence.

CONTRIBUTED REMARKS.

Mr. Alex. Richardson: The Messina Copper Mine is one of the many striking instances of civilization's debt to mining, for it has been the means of creating in the wild Northern Transvaal an oasis of social and industrial progress which will assuredly hasten the development of a vast and little known district. The Company, in the face of great difficulties, has successfully tackled the many mining and metallurgical problems with which it has been confronted; and it is to be hoped that Mr. Whyte's useful paper is the

forerunner of others dealing with the larger aspects of mining or metallurgy.

Having visited the mine a few years ago, I am able to appreciate to the full the author's enumeration of the difficulties in the way of the successful employment of the theodolite for stope measuring; but I think he is a little too uncompromising as regards some of the points. The theodolite can easily be used in places even less than 18 in. in height by placing the instrument directly on a piece of board bedded down on a few handfuls of fines; and the trustworthiness of the Kaffir is not by any means impaired by his working at a much greater distance from the surveyor than 20 ft.—if it were, a great portion of the work of the South African mine surveyor, on the Rand at any rate, would have to remain undone.

Apart, however, from the objections put forward in the paper, it would be, in my opinion, most injudicious to employ a theodolite for the class of work the author describes, for the reason that a valuable instrument of precision should be reserved for work demanding precision and not be used for the comparatively rough work of stope measuring. For such work the miner's dial is admirably suited; and if it is equipped with three tripods, or their equivalents, very speedy progress can be made with it. It allows of change from fast needle to loose needle at will, as the presence or absence of iron may dictate; or the loose needle may be employed throughout, the adjustment of the readings when affected by the presence of iron being easily made, provided that an occasional station in the stope can be found removed from its influence.

In connection with the author's method the following devices might be worth trying: The substitution of brass or copper wire for the string used in ranging the traverse; the addition of a central boss to the polar protractor to enable it to ride more securely on the string; and the use of the extensible rod, suitably graduated, instead of the tape for measuring the offsets. In the ore reserve calculations, logarithms to seven-figure mantissæ seem scarcely called for, as five-figure logarithms will furnish far more than all the needful accuracy. At any time great mathematical refinement is somewhat out of place in the calculation of ore reserves, as so much depends on factors that can only be determined approximately.

The author has worked out a serviceable method for cases where close measurement is necessary, but it would seem to be rather laborious for ordinary routine stope surveying.

There was another paper on the Agenda,

'Platinum in Spain,'

By F. Gillman, *Member*,

which would be discussed by correspondence.

CONTRIBUTED REMARKS

ON

"Hydraulic Tin Mining in Swaziland."

By J. Jervis Garrard, *Member*.

Mr. A. Trevor Roberts: I have read Mr. Garrard's paper with much pleasure, and feel sure that the data contained therein will be found to be of very considerable value, especially those dealing with the efficiency of the various units of the hydraulic plant.

With regard to the dressing of the tin-concentrate, however, I note that after 'streaming,' the product is brought up to bagging-grade by means of a Wetherill separator. This doubtless gives satisfactory results, and under the conditions ruling at Mbabane, may possibly be the only means applicable; but taking all things into consideration, a magnetic separator, of whatever design, is rather an expensive item, especially on an alluvial property, and its elimination can only be an advantage if it be possible to bring the tin content of the concentrate up to the same percentage by other and more economical means.

When power-water is available, this should present no great difficulty, for by means of a small turbine, sufficient power to operate the necessary dressing-machinery can be readily obtained.

One such plant, which happened to come under my observation, consists of two hydraulic-classifiers in series, one shaking-table, one buddle, and one 'Willoughby,' with the necessary screens, pipes, etc., all contained in a compact cement-floored building, and has been treating, for several years, low-grade alluvial tin-ore containing a considerable amount of monazite and ilmenite, at a very moderate cost and with marked success.

I was much struck by the use of pontoons for the support of gravel—and nozzle—pumps; the idea is excellent and is one which, under similar conditions, might with advantage be more generally adopted.

The only precise information given in regard to these pontoons is that each is 20 ft. square, but no mention is made of the depth or of the materials from which they are constructed.

Their erection in or near an industrial centre, would, of course, be quite a simple matter, but in view of the fact that the property of the Swazi Tin, Limited, lies at such a distance from the nearest

have been formed at the end of the magmatic period by the replacement of silicates."*

These two gentlemen have read the literature of the subject carefully and have examined a great number of polished sections from Sudbury and elsewhere, as shown by their references and by the admirable plates accompanying their paper, but they seem never to have studied the field relations as shown, for example, at Sudbury and on the Insizwa Range. The settling of the heavy olivines and of the still heavier sulphides at the bottom of the Insizwa basin and the fact that ores are found only in depressions beneath the norite at Sudbury and never at upward bends of the underlying country rock receive no explanation by their theory; but the most fatal objection to it is found in the enormous amount of pyrrhotite-norite overlying the great Sudbury ore deposits.

Probably half or more than half of the ore of the region is sprinkled as separate pellets through the norite above the main deposits. These pellets or blebs of sulphides may be found hundreds of yards away from the mines, growing fewer in number and finally disappearing. Thin sections of pyrrhotite-norite often show that the enclosing rock is so fresh that even the hypersthenes are unchanged; and neither hand specimens nor thin sections give any evidence of channels by which the little masses of ore could have reached their present positions. These widely scattered pellets of pyrrhotite and chalcopyrite completely enclosed in unchanged norite are easily explained by gravitative segregation as the magma cooled, but are inexplicable by any theory of replacement. A walk of half a mile over the basic edge of the eruptive sheet near one of the great marginal mines near Sudbury makes this absolutely clear.

The weakness of the metallographic method of solving the problems of ore deposits lies in the fact that only the final relations of the minerals concerned are disclosed by the polished sections studied. Their previous history must be determined by broader geológical methods and one must be familiar with the field relationships if correct results are to be looked for.

Though the nickel deposits of the Insizwa Range differ from those of Sudbury in being associated with very basic and magnesian rocks instead of rather acid norites, they furnish an equally convincing example of magmatic segregation aided by gravity; and the fact that similar results are found in sheets of rock which differ so much in composition shows that this method of accounting for sulphide ore-bodies is widely applicable.

It is probable that the Alexo nickel mine, east of the Porcupine

* 'A study of the Magmatic Sulphide Ores'; *Stanford University Studies*, 1916.

gold region, has a closer analogy with the Insizwa deposits than the Sudbury mines, since the sulphides at Alexo are at the base of a mass of serpentine still retaining the forms of olivine crystals. Unfortunately the serpentine area enclosing the ore is poorly exposed, being mostly drift covered, and its wider relationships are not known. One would expect that here, as on the Insizwa Range, the serpentine would pass upwards into olivine-free gabbro or norite.

Though the South African nickel region has not yet furnished deposits of workable dimensions, its investigation has given results full of interest for mining geologists.

Professor Grenville A. J. Cole: I have read Mr. Goodchild's paper with great interest; but I do not feel competent to express an opinion as to the phenomena without personal acquaintance with the masses in the field. The view put forward by the author that the veinlets of microgranite in the contact-region result from a melting of constituents of the hornstones seems to have features in common with that propounded by Professor Schwarz for the classic section in the Malmesbury Series east of Cape Town.

In the latter case some transference of material has taken place from the invading magma to the aureole; but Mr. Goodchild's suggestion involves simpler considerations, and may prove applicable to other cases in which marginal differentiation has been invoked.

There is no difficulty in accepting his view that the argillaceous rocks were not by any means so compact at the time of the intrusion of basic matter into them as they have since become; but I confess that I have nowhere seen evidence of flake-like veins formed by the infilling of shrinkage-fissures in an igneous mass near its margin. Case after case may be cited where such parallel flakes prove to be true inclusions, and the degree of metamorphism undergone by them in various parts of the exposures is by no means constant.

Parallelism among such bodies usually implies that they were originally fairly rigid, and remained in position despite the melting out and replacement of intervening layers; but it may also represent a flow-structure in the composite rock, and may thus be compatible with a certain softness in the mass from which the inclusions were torn off.

May I, as a detail, ask Mr. Goodchild to reconsider the word 'hornfelses,' seeing how familiar 'hornstones' were to our geological predecessors? I confess that the same men used the clumsy term 'greywackes'; but they did not think of writing 'grünsteins.'

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Subject to revision.] [*A Paper to be discussed at a Meeting of the Institution of Mining and Metallurgy, to be held at the Rooms of the Geological Society, Burlington House, Piccadilly, W., on Thursday, May 24th, 1917, at 5.30 o'clock p.m.*

Shall Great Britain and America adopt the Metric System?

By WALTER RENTON INGALLS, *Member.*

(*President, Mining and Metallurgical Society of America; President, American Institute of Weights and Measures.*)

NOTE.—I have sent this paper to the Institution of Mining and Metallurgy in the hope of opening the eyes of its members to a great danger with which it seems to me both Great Britain and the United States of America are threatened by the present strong metric propaganda. Although I have in my paper used American illustrations and references, and there are probably variations in British customs and practices, I feel sure that readers in Great Britain and the Colonies will find no difficulty in applying my argument to the things they know.

THE discussion of the metric system at the meeting of the Institution on Nov. 16, 1916, prompts me to make a communication on this subject. In the United States there is a persistent and insidious effort by theorists to substitute the metric for the existing system of weights and measures. In order to combat this, the American Institute of Weights and Measures has lately been organized. The subject is of vastly greater importance than is commonly comprehended and therefore an earnest propaganda is necessary in order to arouse the people of Great Britain, her Colonies, and the United States to the importance of preserving their interests.

Before entering upon any discussion of the metric system, let a sharp line be drawn between it and the decimal system. The advantages of the decimal system are so manifest in many cases that the prometric party is wont to cloud the issue by making it appear as if the metric system were the only decimal system. Really, there is the fundamental difference that the decimal system *per se* is merely arithmetic, while the metric system involves the basic units of weights and measures. Thus, for convenience, miners and smelters decimalize the ton, railway operators decimalize the mile, surveyors

decimalize the foot, and machinists decimalize the inch. But the basic units remain unchanged.

Another source of confusion will be dispelled if we can eradicate the chimerical idea of establishing uniformity, which in itself is alluring. But from a project that would manifestly put the weights and measures of the greatest industrial nations of the world at sixes and sevens it must be evident that the result would be more discord instead of more uniformity.

We find that the most ardent of the prometric party are those who have to deal with weights rather than with measures. The substitution of metric weights for English weights would create relatively little disturbance. Of course, the changing of all of our weighing scales would cost a huge sum, and the recalculation of schedules—such as railway rates—might come to something like the ransom of an empire, but after these were done, we might get on pretty well.

Personally, although I am strongly antimetric, I employ the metric system of weights in international statistics. Thus, in reporting the statistics of world's copper production, it is easier to convert the American figures into metric tons than it is to convert those of 20 other countries into pounds, although the American production may be 70 % of the total. Moreover, in laboratory work, I use grammes and cubic centimetres, or kilogrammes and litres, both out of convenience and out of early habit in common with that of most chemists. By reason of such habit I visualize and sense the gramme better than I do the ounce, but when I pass to larger weights, the pound means more to me than does the kilogramme.

Similarly, out of habit I think of temperatures according to the Fahrenheit scale up to the boiling point: there is then a range whereof I have no conception: but from red heat upward I think in terms of the Centigrade scale. Of such mental habits and their bearing upon the substitution of the metric system, which I regard as a matter of major importance, I shall say more before concluding this contribution.

If weights and measures were employed merely as means of estimating and recording, there would be no great reasons why the metric system, or the Russian, should not be substituted for the English, save for the cost of providing the new instruments and the slight experience necessary to become familiar with them.

I happened to be operating a mine in Mexico in 1896 when the metric system was made compulsory there. Being law-abiding, we discarded the weights of the *arroba* and the measures of the *vara* and the *fanega* one evening and began with the kilogramme and the metre the next morning. Not even were our simple *peones* and *pelados*

flustered. What difference did it make to the carpenter whether he bought a kilogramme of nails or two pounds? Or to the woman whether she bought a metre of cotton cloth, or a yard? Nor did it make any difference to the company whether it figured its ore shipments in tons of 2000 lb., or of 1000 kg.

It is such apparent simplicity of the change that is illusory and leads the metric advocates to proceed blithely with a programme into which they do not look deeply enough to see the consequences. They regard weights and measures simply as means of estimating and recording. They do not consider the *things* that are tied up with them, or the *knowledge* that is associated with them. By 'things' I mean the standards that have become interwoven in our civilization and industry, upon which indeed civilization and industry are based.

Let me try to make my meaning clear by referring to land measure, a subject with which nearly everybody is familiar. In an unsurveyed country, like parts of Mexico, I can use a 100 m. tape as well as one of 100 ft., and can compute areas in sq. m. as well as in sq. ft. But suppose I am in the United States where most of the land has already been surveyed in ft. and miles and figured in acres and square miles, and I am compelled to divide metrically a Government quarter-section, my troubles would quickly begin. Anybody who has had to tie up with old surveys in New England, recorded in rods, chains, etc., knows what these would be.

Let us consider the conditions that have been established in the railway business of the United States. The tracks are marked with mile posts. The railway gauge is 4 ft. 8½ in. We might in course of time get in the habit of thinking of the latter as 1435 mm., but manifestly it would never be convenient to refer to the mile posts as being 1·60935 km. apart, and either we should have to continue to think of miles, or else pull up the posts and replant them at km. intervals, which would be something of a job. Incidentally, our posting of highways would have to be revised, and the automobilist would mourn the day when metric legislation was enacted.

Returning to the railway business, it is well known that the passenger and freight schedules, which fill great volumes, are based on cents per mile and cents per 100 lb. The railways have complained over the great expense involved in making alterations for the purposes of the Interstate-Commerce Commission. What would it be if the entire fabric had to be torn apart and rewoven in order to please the advocates of the metric system?

A prometric scientist is reported to relate, with great gusto, the following story:—

'I needed to have turned a brass rod 20 mm. in diam. The machinist told me he could not do it. I went home and converted the dimensions into decimals of an inch, after which I asked the machinist to turn a rod 0·7874 in. in diam. He made no bones about it.'

Why should he? He would not undertake to turn the 20 mm. rod, for he had no millimetre scale. The dimension having been converted into decimals of an inch, he was able easily to take that with his calipers from his scale and gauge the rod when it had been turned sufficiently. But suppose this machinist was not doing merely piece work but was manufacturing on a large scale. His hundreds or thousands of workmen would neither have time to gauge diameters with calipers, nor would he trust them to do so. The measures would be done with the aid of standard gauges, conforming to the requirements of practice and convention.

These gauges are based on the inch. If the metric system were made compulsory, it is obvious that there would be but two alternatives, viz., to restamp the gauges with strange and unhandy figures, and wait until people became accustomed to them, as, for example, to ask for a 6·35 mm. rod when they wanted a ¼-in. rod; or else to change the standards so as to make them conform to metric units. Either horn of the dilemma is bad, but the second one—the changing of gauges—would be calamitous. Some large American manufacturers have estimated that such a change would cost them individually from half a million to three-fourths of a million dollars.

So it is with all of our affairs. Our entire system of manufacturing, of building and of doing things is based on standard units, which cannot be changed, except under conditions that would mean nothing less than calamity. Does anybody imagine that a 2 × 4-in. joist could be anything else but a 2 × 4, although it might be called a 50·8 × 101·6 mm.; and after we were given specifications in metric measures, should we not have to translate them back into English measures, in order to make use of our tables of board measure for easy computation?

Of course, we all know that a 2 × 4 is seldom of those exact dimensions, and we should probably call it a 50 × 100 mm. after we had learned the rules of the new game. But sometimes it is necessary to figure closely in connection with joists S4S, and then we know that the 2 × 4 is reduced to 1⅝ × 3⅝ in. How we should conveniently arrive at the exact dimensions of a nominal 50 × 100 mm. joist deponent saith not.

Consider what we do when we get a drawing of a French construction, let us say a metallurgical furnace, to build in this country. The first thing that has to be done is to redraw it, not for the reason that it is expressed in metric measurements, but for the reason that it calls for constituent parts of sizes that are not obtainable here. It is drawn in France so as to dovetail together all sorts of things that are standardized according to metric measures. In America we must use the things that we can get and they are standardized according to inches.

Conversely in drawing something of American practice to be constructed in France, we draw it in our own way and tell them to redraw. It would be easy enough to draw here with metric scales; indeed, in my own practice I put a metric scale on each sheet destined for a metric country; but engineering drawing is something different from the mere use of scales. It is the combination and representation of standard things, and we have to show our own, which we know; not the French, which we do not know; and let it be redrawn in France according to their standards that are nearest to ours. Any change of standards in either metric or non-metric countries is preposterous, unthinkable. We have all gone too far. Besides the colossal expense of substituting gauges the result could not be anything but a mixture. The man who needed some ½-in. bolts for the repair of his automobile would not relish the information that they were no longer made, but that he could have 10 mm. or 15 mm. bolts.

But, say the metricists, 'We do not intend to change the standards. We propose merely to call ½-in. bolts 12·7 mm. bolts, and similarly with other standard manufactures, and this is so that people in Spanish and Portuguese countries, where we hope to expand our export trade, will understand what we are talking about.' There is no argument more childish than this. Why not, therefore, discard the use of the term bolts and substitute the Spanish equivalent?

The manufacturer who is courting export trade in a Spanish country translates his catalogue into Spanish and converts his English measures into their metric equivalent.

The Argentine or Chileño has no difficulty in being made to understand if the British or American manufacturer wants his business. If it be a question of competing with German manufacturers, they will make special sizes for that purpose, just as do foreign makers of automobile tyres who seek business in this country. Our tyre manufacturers would do the same if they wanted competitive foreign business. Nobody has had the

effrontery to propose that the United States should discard its standard inch-sizes and substitute others conforming to foreign practice. The million automobilists would regard such a suggestion as a joke.

Illustrations of how we are tied to our standards may be multiplied endlessly to all intents and purposes, and this union is not merely one affecting the manufacturer, but also is it one that concerns all our accumulated knowledge. The engineer, for example, unless he be directly engaged in manufacturing, is not concerned with the matter of gauges, but his accumulated knowledge of physical constants, of the standards of material, of the units of work and of the cost of doing things constitute a large part of his professional capital, including what is stored in his mind and what is stored in the thousands of books in his library.

All of this is embodied in terms of English weights and measures. We have volumes of tables of figures devoted to the properties of structural steel. Similarly as to mechanics, hydraulics, surveying, in brief all the branches of engineering. With the metric system these would be all but useless. Let us look at a relatively simple matter expressed metrically, viz., the computation of the products of combustion of coal, a problem that is common to the metallurgical engineer. I will translate from Toldt's 'Regenerative-Gasöfen' on this subject.

'1 kg. of air = 773·39 litres; 12·71 kg. = 9829·79 litres. According to the Gay-Lussac law, 1 cub. m. air weighs at t°C and at a pressure p kg. per sq. m.;

$$1 \text{ cub. m. air} = \frac{1\cdot252 \text{ p kg.}}{1 + \alpha \text{ t.}}$$

Assuming a mean temperature of 23·7° C. and a barometric pressure of 703 mm., the weight of a cub. m. of air is 1·104 kg., and 1 kg. of air = 905·8 litres.

If 1 kg. of carbon be burned in atmospheric air to carbon dioxide, there will result 3·67 kg. CO_2 and 8·94 kg. N. The volumes will be 3·67 × (1000 ÷ 1·965) = 1867·663 litres of CO_2 and 8·94 × (1000 ÷ 1·2544) = 7126·913 litres of N, a total of 8994·576 litres of combustion products.'

For the American and British engineer this might as well be written in Latin. Indeed, the compulsory adoption of the metric system would be no less preposterous than an edict that after a certain date all business in the United States—all buying and selling, all engineering, all figuring—would be illegal unless done in French. Either in French or in the metric system it would be possible to get along with the aid of the dictionary or conversion

table and with constant use of pencil and a pad of paper. Imagine the motor-cycle policeman pausing in his chase of the automobile speeder to compute whether he were breaking the speed limit in kilometres per hour.

This brings us to the psychology of weights and measures in our daily life. I have referred previously to how some people think metrically of certain things and non-metrically of others. Neither the locomotive engineer nor the automobilist has to look at his speedometer to tell approximately how fast he is going in miles per hour. He knows. But he would have to perform a mental calculation to say it in kilometres.

The association of things of observation and experience is indeed the reason why certain of our old English measures, long since discarded generally, linger in special use. Thus the sailor speaks still of knots and fathoms, for he thinks in them. The hand as a measure of length has disappeared from usage except in indicating the stature of horses. Tell a horseman that a colt is 62 in. high, or 5 ft. 2 in. high, and it means little or nothing to him. But say that it is 15½ hands high and he immediately visualizes it, mentally comparing it with other colts of that known height.

Similarly does the chemist sense weights in grammes, while the apothecary does it in ounces. Such habits are not easily altered. Thus we find in France the use of ancient weights and measures, and the thinking in terms of them, lingering more than a century after the adoption of the metric system.

Having pointed out the objections to the compulsory adoption of the metric system, I hope effectively, even if but generally, let us consider the arguments that are offered in favour of it.

The prime argument is to have international uniformity. It is stated that a long list of the countries of the world have adopted the metric system, *only* the United States, Great Britain and her *Colonies*, and Russia (of the Indo-European nations) having failed to do so. I have italicized the words *only* and *Colonies*, for therein is concealed the speciousness of this argument. If with 'Colonies' we equate Canada, Australia, New Zealand, Tasmania and South Africa, we have a longer list of non-metric countries, and it comprises not only the most populous, but also the most industrial nations of the world.

A correct statement of this theorem would be: Considering the Indo-European race alone, there is a much larger population that does not use the metric system than does; and their nations are far superior in industrial development, measured by iron production, let us say, to all other nations combined. The foisting of the metric

system upon them would be, therefore, like letting the tail wag the dog.

If uniformity be the objective, it would be better to institute a propaganda to induce Germany, France and the Latin countries to adopt the English system. In this connection it may be remarked that, although Russia has a system different from either, the fundamental Russian measure of length, which is the most important of all measures, is the foot, and the Russian foot is the same as the English.

Another argument on the ground of uniformity relates to the confusion existing in the English system owing to the different kinds of tons, pounds, gallons, etc. That there is such confusion, with its inherent dangers, is true; but it is also true that the confusion is much less now than it was twenty years ago, that it is bound to experience further reduction, and that it may be eliminated entirely in a way far easier than by the introduction of the metric system.

In Great Britain there is but one kind of ton, viz., that of 2240 lb. In the United States, the English, or long, ton is employed to far less extent than formerly, and in the main we have standardized the ton of 2000 lb. That we should have two pounds—the avoirdupois and the troy—is annoying, but the annoyance is now more academic than practical, for the troy pound is seldom used. Similarly have the differences among gallons, bushels, etc., lapsed in the main into innocuous desuetude.

But with respect to confusion, the skirts of the metric system are not clean. As a statistician of nearly thirty years' experience I may say that I have fallen into more errors over the zentners and doppel-zentners of metric Germany, and the quintals and metric quintals of Chile, than I have over the pounds of England and America and the poods of Russia.

The third metric argument is the ease of the calculations, especially the correlation among measures of length, volume and weight. It may freely be admitted that there is some merit in this, but further on I hope to show that the English system is not quite helpless in this respect; and that the superior merit of the metric system is far short of being a determining factor, quite apart from its calamitous effect in overthrowing existing standards and upsetting the mode of thought of the people, which of course are the major considerations.

We come now to the alleged advantage of the metric system in promoting foreign trade, a matter that I have previously touched upon lightly in this paper. Listening to the metric advocates,

it might be imagined that Great Britain and the United States had no export trade with foreign countries before the War, and that the only way for them to compete with Germany after the War is to adopt the metric system because Germany will offer goods made according to it. We of the United States look upon Russia, China and South America as the regions of the world with which to build up great trade after the War. We had large trade with them before the War, and so did Great Britain, in spite of non-compliance with the metric system.

We hope and expect that after the War it will be greater. But in making it greater, we are encouraged to think that the fundamental ideas are to offer them useful things, excellently made, through well-conducted agencies and by means of models and descriptions in their own languages, also dimensions with metric equivalents if they wish. And having interested them to the point of buying, we must extend to them the banking credits they need, and must pack the goods in such a way as will cause them to be delivered safely and will permit inland transportation by crude methods.

In many of these respects Germany formerly excelled us, largely owing to our indifference in this trade, but successful competition with her in the future is going to be based upon such major points as I have mentioned, and not upon the very minor one of making goods according to metric measurements. Does any one imagine that Russia is not going to buy McCormick reapers and Ford automobiles, that China is not going to buy American kerosene lamps and stoves, that South America is not going to buy Baldwin locomotives, because they are built to sizes of the inch and multiples thereof?

Ingersoll-Rand rock drills are sold in every part of the world, and will continue so to be sold for the reason that they are good drills and the company pursues good business methods, including the maintenance of stores with repair parts at many centres. The Chilean, the Chinaman and everybody else is going to buy the rock-drill, the automobile and all other machines that he can most easily repair, original qualities being equal; and he is going to be swayed by such common-sense reasons, not by metric dimensions.

One other argument for the metric system is the alleged simplicity with which it can be acquired by schoolchildren. I do not believe that is so. Without having had any experience in school teaching, it has nevertheless been my good fortune to observe and supervise a number of children during their passage through the grammar school. In mental quality they have been better than the

average. Without exception they have had difficulty with the metric system.

This has been partly due to the clumsy method of teaching it, the emphasis put upon learning a long list of strange names like the millilitre, centiare, decastere, etc., which, of course, are not used in real life, even by metricists. But there seemed to be a deeper reason, which is not peculiar to the metric system, but pertains to any decimal system, viz., the difficulty of the youthful mind in grasping the idea of decimal fractions.

Vulgar fractions are comprehended more easily. This ought not to be so, but apparently it is. I think it arises from the natural tendency of all of us first to divide an integer into halves. Suppose one has a stick that he wants to divide into equal parts and has no scale. He gauges the length with a string and doubles it, getting halves; then he doubles it again and gets quarters. He cannot get thirds, or fifths, or tenths by any such simple method. The human predilection toward the binary division probably dates back to the time of the Cro-Magnon race and never will be eradicated.

In drawing this long paper to a close, let me revert to the philosophy of weights and measures. All of our systems, including the metric, are undergoing evolution, conforming to the requirements and practices of people, generally in the direction of simplicity. Most of the old English measures to which the metricists point with such scorn are obsolete. Nobody hears nowadays of the coomb, the pottle, the chaldron, the palm or the barleycorn. The perch, the puncheon, the span, the tierce and the toise are all but forgotten. Even the furlong, the gill and the rod are disappearing.

But so also with the metric system. The noble hierarchies of measures beginning with the millilitre and running up to the myriolitre, that running from the are to the hectare and the other from the stere to the decastere have been forgotten. In weights we talk of tons, kilogrammes, grammes and milligrammes; in long measure of kilometres, centimetres and millimetres, in square measure of hectares, in volume of cubic metres, litres and cubic centimetres, and we neither use nor think of much else.

Both in the use of the metric system and the English there are three well defined tendencies. These are to discard unnecessary units and multiples, to employ measures of weight instead of those of volume wherever possible; and where not possible to substitute cubic measures for special forms. The first of these tendencies requires no elaboration. The second is due to the desire to obtain a degree of precision in matters of retail trade that otherwise is impossible. The housewife cannot buy a peck or a litre of potatoes

and be sure of just what she is getting, but she can be when she buys in pounds or kilogrammes.

Sometimes the use of the old measures is retained merely as a manner of speaking. Thus the farmer talks about taking so many bushels of corn to the mill. What he really does is to take the corn there, weigh it in pounds, divide by 56 and call the quotient bushels. He does not measure the corn by volume at all. Some day he may forget to talk about bushels and will simply talk about pounds. Perhaps a reason why he continues to talk about bushels is that old records are expressed in such terms and he must continue to have such an expression for sake of comparison, which is only one other instance out of thousands of how in weights and measures the present is linked irrevocably with the past.

But there are many cases where weighing cannot be substituted for measuring. The vendor of gasoline, for example, would find it very difficult to weigh whenever a motorist called. We buy apples by the barrel and milk by the quart because those measures are the most convenient. Nevertheless, there is a constant tendency to substitute cubic measures for the old ones.

Thus our municipalities more and more sell us water by the cubic foot rather than by the gallon. This is because we visualize cubic measures better than anything else. The basis of all measures, using the term in distinction to weights, is the measure of length. Derived from it are the measures of area and of volume.

There are not many people, other than those who have to use it habitually, who have even an approximate conception of what is a bushel; but talk about the cubic foot and everybody can picture it, for everybody knows what a foot is. It is for the same reason that the metricist talks about cubic centimetres and not of millilitres; of cubic metres not of steres.

I trust that I have made it clear that my argument against the metric system is not inspired by blind prejudice against an innovation. On the contrary, I remember the time when I was in favour of its adoption in the United States, and it was not until I had studied the matter more carefully that I changed my mind about that.

The metric system has many good points, chief of which is the correlation among measures of length, area, volume and weight; but if we remember that a cubic metre of water weighs a ton we find no difficulty also in bearing in mind that 1 cub. ft. of water weighs very close to 62·5 lb., or $\frac{5}{8}$ cwt., and that 32 cub. ft. of water weigh one ton of 2000 lb.

In hydrometallurgical work we tend to reckon water and solutions

by the ton rather than by the gallon or even the cubic foot, and some metallurgists have adopted the conventional fluid ton of 32 cub. ft. Whether this be a wise innovation or not I shall not venture to say. The important point is that in remembering the weight of a cubic foot of water, which is one of the constants that every engineer keeps in his mind, just as he does pi r^2, it is just as easy to tie up with specific gravity in estimating the weight of materials as it is in the metric system.

It is indeed far more convenient to British and American engineers, who do not care to know the weight in kilogrammes of a cubic metre of lumber for the purpose of computation, but do want to know the weight of a cubic foot in pounds, inasmuch as railway schedules, the bearing power of soils, the strength of columns and all the engineering data that we possess are recorded in pounds.

Nor do I claim the English system to be perfect and consequently not to be touched. On the contrary, I have shown previously how it has experienced evolution and certainly it is capable of much further improvement, which undoubtedly will come about. What forms the improvements may take I shall not attempt to indicate more than briefly. It seems to me that we shall see a reduction in the number of units in common use, say to a list comprising the mile, the foot and the inch; the ton, the pound and the ounce: the acre.

For all other forms of square measure and for all forms of cubic measure, we may base on the foot. These few measures will be decimalized to a greater and still greater extent. The surveyor already uses the tape of 100 ft. and divides the feet into tenths. The machinist decimalizes the inch. The architect reckons roofing, painting, etc., in 'squares' of 100 sq. ft. The water and gas companies provide us with meters reading cubic feet and tenths thereof.

I hope to see the day when our legislatures will cease muddling over the size of barrels and let each industry adopt what suits it best, subject only to the requirement that its capacity in cubic feet and decimals thereof shall be marked upon it. We should like to see Great Britain adopt the ton of 2000 lb. and decimalize her coinage on the basis of the pound sterling. Not to ask Great Britain alone to give way, let us adopt her gallon of 10 lb. of water, if gallons we must continue to use, as no doubt we shall have to for a long time yet. Let both Great Britain and the United States abolish the troy pound.

In conclusion, I desire to make it quite clear that my argument

in this paper are not directed against the metric system, but rather against the propaganda for the *compulsory* adoption of it. The metric system is already legal in the United States, has been for many years. Anybody is free to use it who wants to, and contracts expressed in its terms are perfectly good contracts. The aëronautical engineers dealing with a new art, which has no links with the past, could reasonably adopt the metric system and have done so.

The Nordberg Manufacturing Co. builds Diesel engines by this system, and the Ingersoll Rand Co. so builds Rateau turbines. But let it not be forgotten that even in Germany an inch-rod is still an inch-rod, no matter what it may be called in millimetres.

*** *Extra Copies of this paper may be obtained, at a nominal charge, at the Offices of the Institution, 1, Finsbury Circus, London, E.C. 2.*

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The Institution of Mining and Metallurgy.

(Founded 1892—Incorporated by Royal Charter 1915.)

Bulletin No. 153.

JUNE 28TH, 1917.

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LIST OF THE OFFICERS
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The Institution of Mining and Metallurgy
1917-1918.

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the alifications of Candidates for Admission into the Institution fulfil the requirents of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be en for inspection at the Office of the Institution for a period of at least two nths from the date of the Bulletin in which their applications are announced.

The following have applied for admission since May 17th, 17:—

) MEMBERSHIP—

Cole, Arthur William John (*London*).
Erskine, Charles Howard (*Filabusi, Southern Rhodesia*).
Whittingham, Harold (*B.E.F.*).

) ASSOCIATESHIP—

Bentley, Alfred Mulock (*Bwana M'Kubwa, Northern Rhodesia*).
Scott, William Robert Wilson Ronald (*B.E.F.*).

) STUDENTSHIP—

Lawford, Evelyn Godfrey (*B.E.F.*).

The following have applied for Transfer:—

) MEMBERSHIP—

Fairbairn, George (*B.E.F.*).
Girdler-Brown, Frank William (*Roodepoort, Transvaal*).
Oliver, Leonard Camroux (*Avantapur, India*).
Pearson, Reginald George (*B.E.F.*).

) ASSOCIATESHIP—

Cronshaw, Harry Brenan (*Galway, Ireland*).
Skelton, Richard Hugh (*Springs, Transvaal*).

NEW MEMBERS.

The following have been elected (subject to compliance with the conditions of the By-Laws) since May 17th, 1917 :—

To Membership—

Harland, Robert Main (*London*).
Leighton, Ernest William (*London*).

To Associateship—

Glen, Alexander (*B.E.F.*).
Haughom, Oscar (*Flekkefjord, Norway*).
Jones, John Evans (*B.E.F.*).
Loring, Edward Amos (*London*).
Wilson, Robert (*Rio Tinto, Spain*).

The following have been transferred :—

To Membership—

MacDonald, Donald John (*Tarquah, West Africa*).
Vecelli, Cesare (*Iglesias, Sardinia*).

To Associateship—

Barrett, Victor Holmes McNaghten (*B.E.F.*).
Bose, Aloke (*Rauchi, India*).
Clarkson, Stanley William (*Perak, Federated Malay States*).
Hill, Laurence Carr (*B.E.F.*).
Leighton, Frederic William (*B.E.F.*).
Mansfield, Francis Turquand (*B.E.F.*).
Warren, Richard Montable (*Cerro Muriano, Spain*).

MOVEMENTS OF MEMBERS.

Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. Bentley H. McLeod, Stud. Inst. M.M., has returned to England from Mexico, and is now in the R.F.C.

Mr. B. Trevor Phillips, Assoc. Inst. M.M., has returned to England from Celebes on leave until October.

Mr. John Reed, Assoc. Inst. M.M., has returned to England from the Republic of Colombia.

Mr. T. J. Rickard, Assoc. Inst. M.M., has returned to England from Siberia, *via* Japan.

Mr. Arthur J. Russell, M. Inst. M.M., has returned to England from the Republic of Colombia.

Mr. F. L. Terrell, Assoc. Inst. M.M., has left England for Northern Nigeria.

Mr. G. Gordon Thomas, Assoc. Inst. M.M., has left the Anglo-Continental Mines, and is now with the Jos Tin Areas (Nigeria), Ltd., Naraguta.

Mr. J. T. Warne, Assoc. Inst. M.M., has left England for the Gold Coast Colony.

Mr. A. B. Watson, Assoc. Inst. M.M., has returned to England from the Gold Coast Colony.

ADDRESSES LOST.

F. B. Bradshaw, O. L. de Lissa, and D. Nicholas.

INDEX OF RECENT BOOKS.

NOTE.—Books marked with an asterisk are contained in the Library of the Institution.

ELEMENTS OF MINERALOGY, CRYSTALLOGRAPHY AND BLOWPIPE ANALYSIS. A. J. Moses and C. L. Parsons. Fifth Edition. New York: D. Van Nostrand Co. $3.

ENGINEERING ANALYSIS OF A MINING SHARE. J. C. Pickering. New York: McGraw-Hill Book Co. 6s. 3d.

*GEOLOGIC FORMATIONS OF CALIFORNIA. J. P. Smith. San Francisco: California State Mining Bureau.

*GLADSTONE MINERAL DISTRICT, TASMANIA. W. H. Twelvetrees. Launceston: Tasmania Geological Survey. 2s. 6d.

*MINERAL PRODUCTION OF THE UNITED STATES IN 1915. H. D. McCaskey and M. B. Clark. Washington, D.C.: United States Geological Survey.

MINERAL RESOURCES OF OREGON. H. M. Parks and A. M. Swartly. Corvallis: Oregon Bureau of Mines.

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ECONOMICS OF MINING AND METALLURGY—*continued.*

Ethics of the Petroleum Geologist. F. G. Clapp.—Economic Geology, Lancaster, Pa., Vol. 12, February-March, 1917, pp. 105-37. 50c.

Flotation Litigation. T. A. Rickard. — Mining and Scientific Press, San Francisco, Vol. 114, April 14, 1917, pp. 501-7. 15c.

Mine Taxation. — Mining and Scientific Press, San Francisco, Vol. 114, April 14, 1917, pp. 499-500. 15c.

Need and Advantage of a National Bureau of Well-Log Statistics. Discussion. — American Institute of Mining Engineers, Bull. No. 124, April, 1917, pp. 635-40; Bull. No. 125, May, 1917, pp. 833-4. $1.

Operation of the Yukon Placer Act. C. A. Thomas. — Engineering and Mining Journal, New York, Vol. 103, May 5, 1917, pp. 782-5. 15c.

Organization of Mine Labour on the Witwatersrand. E. M. Weston.—Engineering and Mining Journal, New York, Vol. 103, April 14, 1917, pp. 656-9. 15c.

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Quotations of Zinc Ore prices.—Engineering and Mining Journal, New York, Vol. 103, May 5, 1917, p. 781. 15c.

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MILITARY SERVICE.

SUPPLEMENTARY LIST.

The following have been notified since the issue of the last Bulletin, May 17th, 1917:

MEMBERS SERVING WITH H.M. FORCES.

BLYTH, W. BERNARD, Royal Engineers, (2nd Lieut.).
GRAHAM, J. H., Australian Imperial Forces.
ROBERTSON, KENNETH, General Service, (Captain)..
TROW, R. M., Canadian Engineers, (Lieut.).
TUTE, H. A., Royal Engineers, (2nd Lieut.).

PROMOTIONS OR OTHER CHANGES.

BODY, W., Royal Engineers, (2nd Lieut.).
BRAY, F. P., Royal Engineers, (Major).
CHARLTON, B. H., M.C., Yorkshire Regiment, (Major).
GRIMLEY, P., Royal Engineers, (2nd Lieut.).
KELLETT, A. G. REID, South Wales Borderers (Pioneers), (Captain).
JOHNSON, E. L., Royal Engineers, (Captain).
METCALFE, H. W., Trench Warfare Research Department, (Captain).
MOUNTAIN, H. G., Royal Engineers, (Lieut.).
PATERSON, G. S., Royal Garrison Artillery, (Captain).
PATON, R. KNOX, General Service, (Captain).
SHEPHERD, S., Royal Engineers, (Captain).
THOMAS, F. W., Royal Engineers, (Lieut.), (attached to Royal Flying Corps).
THOMSON, D. M., Royal Engineers, (2nd Lieut.). *Awarded the Military Cross.*

KILLED IN ACTION.

SELWYN GOLDSTEIN, *Member*, Lieut., Royal Engineers. (*In France, June 8th, 1917.*)

JOHN INGRAM MULLANIFFE O'BEIRNE, *Student*, Observer, Royal Flying Corps. (*In France, April 3rd, 1917.*)

ROBERT CECIL STABLES, *Student*, 2nd Lieut., Indian Army Reserve of Officers. (*In Mesopotamia, May 13th, 1917.*)

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THE INSTITUTION OF MINING AND METALLURGY.

TWENTY-SIXTH SESSION, 1916-1917.

SIXTH GENERAL MEETING,

Thursday, May 24th, 1917.

Held at the Rooms of the Geological Society, Burlington House, Piccadilly, W. 1.

MR. EDGAR TAYLOR (*President*) in the Chair.

DISCUSSION

ON

Shall Great Britain and America adopt the Metric System ?'

By WALTER RENTON INGALLS, *Member*.

The President thought that Mr. Ingalls' paper would be found extremely interesting and would undoubtedly give more than usual opportunities for discussion. He would remind the members that the metric system was not the only decimal system.

He then called on Mr. Sulman to introduce the paper.

Mr. H. L. Sulman said he had the honour to open a debate of exceptional importance, but regretted that he could not approach the subject with impartiality, or start the discussion upon an even keel, as his opinions were already strongly polarized; he was in complete sympathy with the author in protesting against the attempt to foist the Metric System of weights and measures upon the mining, metallurgical, and other industries of English-speaking people.

He had been Chairman of the 'Weights and Measures Committee' of the Institution of Mining and Metallurgy, which for several months during 1906/07 was engaged in standardizing the mining and metallurgical measures employed throughout the British Dominions; as one result of its work that Committee found itself unable to recommend the adoption of the Metric System, this question having been specifically referred to the Committee for consideration.

It had been circulated to all members so far as they could be reached by post, in the terms: 'Do you consider that the general adoption of the Metric System of weights and measures would be feasible in mining and metallurgical work, or would this in your opinion lead to undue dislocation?'; 283 answers were received which were almost evenly balanced—viz., for the adoption, 133; against adoption, 130; undetermined, 20—no recommendation could therefore be made.

He might say he entered upon the investigation strongly favouring the Metric System, and believed this to have been the case also with most of his colleagues; they also had the advantage, on two or three occasions, of the light and leading of the Secretary of the Decimal Association, an official advocate of the Metric System; therefore they commenced not only with a predilection towards it, but had expert advice to shape their opinions. Nevertheless, the result was that they became convinced that the introduction of the Metric System would cause chaos for years, and would thus be disastrous to the industry it was their duty to aid. Had the 133 members who voted in favour of adoption been able to have the same data before them, he thought their number would have been materially reduced.

They were mainly concerned with the industries of Mining and Metallurgy, and it would be difficult to choose an authority more competent to deal with the incidence of the Metric System on these than Mr. Ingalls, whose work in the collation of statistics of the metalliferous mines and markets of the world was unique; if anyone had had the opportunity of appreciating the strong points of the Metric System, surely it was the author. That he had so completely decided against its compulsory adoption was as strong an argument of experience as he (the speaker) could desire.

He would leave the practical engineers present to indicate what was likely to be the dislocation involved in time, effort, and money, and the scrapping of perhaps millions of pounds' worth of plant, and what were the advantages to be gained, by changing over from the units now used throughout the British Empire to those of the Latin, and of the Central Powers of the Continent. It was curious to recall that here, on 'Empire Day,' they were engaged in discussing a proposal to abandon standards of British origin and of world-wide employment, to reject modifications which would bring us more closely into line with our self-governing Dominions and with the United States of America, and to substitute therefor a mathematical Utopia, of limited industrial scope, and to take a decision which would rejoice our enemies in regard to their after-

trade. Surely this, as the author said, was the 'tail wagging dog' with a vengeance!

f he spoke in generalities which might appear threadbare, he at t performed a service in thus clearing the ground for later ıkers; further, the value of generalities was sometimes over-ounted. No one was so stupid as to quarrel with a proposal for decimalization of units within due limits; what they opposed change of the units to be decimalized. They were asked to up the basic units of foot and lb. for the mètre and kilo-mme, but the latter were only pseudo-scientific substitutes; the re itself was based upon an erroneously measured fraction of arth-quadrant, and had no more absolute scientific value than other empirical unit. It certainly had not the sanction of such uries of usage as had the former, nor to the extent to which had become part of our senses and automatic perceptions in alizing weights and measures.

he advocates of the Metric System adopted the attitude that lish-speaking countries used non-decimal weights and measures ch were chaotic in number and subdivision; that these re-ed years to learn, and were at best but a tangle of obsolete ırdities. They instanced the dual use of Troy and Avoirdupois ght for the same ore; and paraded the scruple and drachm, pint and pottle, the bushel, hogshead, and acre, for derision, ging them to have little or no correlation, and therefore to e a vast aggregate of human energy in the simple conversions eights into volumes, and so on. Their view was that if we ıed to decimalize, simplify, and render uniform our system of hts and measures, the only plan was to throw the whole lot board, lock, stock and barrel, our only true salvation being Metric System; that we were bound to adopt the gramme and mètre because the ton, the lb., the mile, the foot and the n were hopeless to decimalize. These arguments were as ıswerable as that the cure for corns is amputation of the leg.

ıe agitation to abandon our present standards and supersede ı by the Metric System appeared to lack perspective. It was ıobby of the pure scientist who, from experience of its unques-d convenience in the laboratory, and its general adoption for essing physical constants, betrayed impatience that national industrial conditions should lag behind his laboratory practice mathematical ideals. He appeared unable, or unwilling, to ze the vast dislocation of effort and material entailed by what garded as a comparatively simple and easy change. Indicate m the millions of expenditure and the 'time-lag' this would

involve and he would cheerfully reply, 'Yes, perhaps two or three days of our present war expenditure'; and 'In but a few years, a generation at most, everybody will think metrically.' This lack of tolerance seemed characteristic of the system, which tended to turn philosophers into fanatics, who, when engineers pointed out that the facts of their vast industries were against such wholesale simplification, exclaimed, 'Then so much the worse for the facts!'

But the incursions of the pure mathematician into complex manufacturing technics, such as our own, were not always attended by our complete enlightenment. They would recall that he had proposed to quantify the efficiency of the stamp and the tube-mill, the roll, and the Chilian mill by hypothetical units based upon Kick's law, itself a high-and-dry mathematical conception applicable only to a strictly homogeneous substance, whilst the whole of our crushing practice depended upon the precisely contrary requirement, namely, success in separating the constituents of a heterogeneous mass. So also with the grading of the crushed products; here mathematicians had sought to lead them into complex seriations of aperture-width founded on mathematical ideals difficult of realization, practically meaningless if realized, and involving conditions of accuracy far beyond the limiting facts of the case. Whilst Science had been defined as 'measurement' it had been more aptly described as 'organized Commonsense,' and insistence on mathematical perfection when this would lead to disorder in other respects was less science than pedagogy.

A fact sometimes in danger of being missed, was that the Metric System had no exclusive freehold right to decimals; it was open to them to realize many of the advantages which the Metric System loudly proclaimed as its own, by decimalizing their standards, so far as desirable, without inviting the chaos for a generation, and the untold expenditure, involved by a change of unit.

Several desirable simplifications were quite easy of adoption. Mr. Ingalls in one of the latter paragraphs of his paper said, 'I hope to see the day when our legislatures will cease muddling over the size of barrels and let each industry adopt what suits it best, subject only to the requirement that its capacity in cubic feet and decimals thereof shall be marked upon it. We should like to see Great Britain adopt the ton of 2000 lb. and decimalize her coinage on the basis of the pound sterling. Not to ask Great Britain alone to give way, let us adopt her gallon of 10 lb. of water, if gallon we must continue to use, as no doubt we shall have to for a long time yet. Let both Great Britain and the United States abolish the Troy pound.'

at was written in 1917. In 1907 the Institution of Mining and llurgy circulated the following recommendation to its mem-iip throughout the Empire: 'The word "ton" shall represent ight of 2000 lb. Avoirdupois'; followed by the note: 'It is able to abandon the use of the terms "hundredweights" and rters" and to express fractions of ton in pounds or decimals of .' The next recommendation was that 'the word "gallon" represent an Imperial gallon of 10 lb. of water.'

a further recommendation which, whilst not advising the donment of the Troy ounce, recognized the desirability of a ler relationship between weight and value, it was stated : 'The gold contents of ores, determined by assay, shall be ssed in money values as well as weights.' This was a tenta-step towards simplification, the value of the Troy ounce of gold ; taken as 85*s*. sterling, which incidentally meant that the nyweight' of gold was the dollar, within a minute fraction.

was gratifying to see that what the Institution advised in 1907 uthor of the paper now ably and eloquently confirmed.

it as to values, chaos in units still persisted between the ric' countries themselves, and the franc, mark, lire, and a still required translation from one to the other. On the : hand, as had oftentimes been pointed out, English-speaking les had a much wider basis for uniformity of currency in the r, i.e. the 100 cents or half-pennies; the cent was of the value throughout the world, whether in England, the United s, Canada, Australia, New Zealand, South Africa, etc. If it ared safe, therefore, to prophesy that the dollar would never iperseded by the mark or the franc, it was not unreasonable to that the pound would in the future continue to be just as ly employed.

ie Metric System, apart from the laboratory, was certainly of as a species of 'Esperanto' in weights and measures, offering ivenient method for translating units of mensuration of one try into those of another; but it was to be hoped that for us ompulsory adoption was as far distant as the compulsory itution of Esperanto or Volapuk for the English language.

'en Decimalization was not a synonym for Salvation. The ce of mathematics, with its provinces of decimals, duodecimals, even our very system of numeration, were after all merely in creations, and (like all such conceptions) had a strictly tionary history; there was nothing of the nature of 'Revealed h' about them. Our numeration was decimal of course ise of Man's possession of ten fingers. Had he evolved a

six-digit hand we should doubtless have inherited a duodecimal scale of notation, and it would have been as difficult to think in decimals as in septimals; a position which might not have been without its advantages. Yet before he could count up to ten, man began to think in 'twos' and 'threes.' It did not follow, even yet, that our numerical conceptions were more readily grasped if expressed as decimals. The ordinary man visualized the simpler fractions, the quarter, eighth, sixteenth, etc., much more easily than their decimal equivalents: we were not all professors, and for most these proportions were easier than 0·25 or 0·125, 0·0625, to say nothing of the ponderous mess that decimals make of 'thirds' and 'sixths.'

Any rational system of multiples or divisions would employ the duodecimal as well as the decimal; it was obviously advantageous to have a system of measures capable of division by 2, 3, 4, and 6, rather than by 5 or 10 alone, and according to which simple fractions like thirds, and even 32nds and 64ths, would not run into expressions as long as one's arm.

One frequently heard the Metric System extolled for the extreme simplicity of its calculations; apparently in most cases all that was required was to take a unit or two with a few noughts behind it, and divide or multiply it by another unit, with a tail of noughts, then to take away the number of noughts first thought of, and the result was obvious at a glance. But occasionally the difficulty was to decide where that 'damned dot' (as Lord Randolph Churchill expressed it) came in, and a small mistake of a hundred or thousand per cent. could readily be made by the very 'simplicity' of the operation. Though of course not a serious argument, this contained a percentage of truth which some would secretly acknowledge.

Having now occupied their attention for what the late Sir Frederick Bramwell once called 'point 333, etc., of an hour' he would leave the question to its closer debate.

The President said he would call upon Mr. Harry Allcock, the author of a most valuable lecture delivered recently before several kindred Institutions, to open the discussion against the arguments used by the author. Mr. Allcock had kindly come down specially from Manchester to favour them with his views.

Mr. Harry Allcock said that before dealing with the contents of the paper he would like to say that he was the victim of two disappointments. In the first place he had hoped to be able to join with the members in welcoming Mr. Ingalls to a meeting of British mining engineers. Mr. Ingalls was a gentleman of very consider-

able eminence and attainments in America, and it was accordingly all the more to be regretted by many of those present that, in his capacity as President of the American Institute of Weights and Measures, he had accepted a broom with which he apparently hoped to stem the metric tide. The metric tide was approaching the full, and it would be very much to be deplored if a gentleman of Mr. Ingalls' parts were to be swept off his feet by that tide. Again, he had wanted to meet Mr. Ingalls so that he might have the benefit of one of those after-meeting conversations with him over their coffee, which were frequently so very much more interesting because all formalities were broken down, and to hear from him what his objections really were, because to his mind none of those advanced in the paper was insuperable.

Then he had had a further disappointment, in that owing to an unfortunate misdirection he had been unable to reach the meeting in time to hear the first part of the remarks of the gentleman who had opened the discussion in Mr. Ingalls' unavoidable absence. With his permission, he would therefore leave that gentleman's remarks to be dealt with by subsequent speakers, and would devote himself to the arguments advanced in Mr. Ingalls' paper, a copy of which the Secretary had been kind enough to send him.

Reviewing those arguments one found several admissions which, when followed to their logical conclusion, provided striking testimony in favour of the reforms which the author had set out to oppose. For instance, although America and the United Kingdom were claimed to be strong adherents of what was honoured by the name of the Imperial System (?) of Weights and Measures, they had the author's admissions, in his Introductory Note and elsewhere in his paper, that the application and practice of that so-called system differed in those two countries.

When they added to that the statement made by the late Sir William Preece in 1908 that we employed 154 different units of length, and the further fact quoted in the House of Commons by Sir Henry Norman in 1907 that we employed 200 different weights and measures in the British corn trade alone, one could quite appreciate the author's further admission that reform was urgently necessary.

Now along what lines should such reform be attempted? The author said on p. 1, 'The advantages of the decimal system are manifest,' and on p. 2 he said 'The idea of establishing uniformity is in itself alluring.'

They must all admit that our adoption of the Metric System would secure for us both these advantages, in addition to others

incidental to that system. On the other hand, if we followed the author's advice and decimalized our existing units of weights and measures we should thereby accept all such difficulties as were incidental to any change, and in the end find ourselves in the possession of an inherently bad system because of the absence of correlation between our units of length, weight, volume and area.

On that question he might perhaps refer to the recommendations of a Select Committee of the House of Commons so long ago as 1862, which reported in these words: 'It would involve almost as much difficulty to create a separate decimal system of our own as simply to adopt the Metric System in common with other nations. And if we did so create a national system, we would, in all likelihood, have to change it again in a few years, as the commerce and intercourse between nations increased, into an international one.'

That was fifty-five years ago, and if the Committee of the House of Commons, with the information then available, anticipated the possibilities of a further change when the volume of international trade had developed sufficiently, what would they have said under the present conditions of enormously increased international trade, and what therefore ought we to say on the same problem? It must also be recognized that if we proceeded along the alluring path of decimalizing the pound, the gallon and the yard and so forth, we should remain as far off as ever from the ideal of uniformity with other nations.

Before leaving the question of correlation between units he would like again to refer to the paper. The author said on p. 8 in regard to correlation: 'It may freely be admitted that there is some merit in this,' and again on p. 11: 'The metric system has many good points, chief of which is the correlation among measures of length, area, volume and weight.'

On the question of uniformity the author suggested—he could not think seriously—that if uniformity was so desirable, why did we not go into the metric countries and ask them to accept the English units? Well, metric advocates realized some of the difficulties of bringing about any change even when they had on their side all the arguments, all the scientific structure of the Metric System, and every advanced view in science and industry. If they realized the difficulty, what would the poor fellow do who went into a metric country to urge their adoption of our chaotic and cumbersome jumble of tables which we chose to call a system? He was sure they would all agree that such proposals would be met with ridicule, and ridicule would break the hearts of any such missionaries—if indeed such could be found.

Then it must be remembered that if uniformity was desirable—and he thought in these days everyone was prepared to admit that it was—it must come down ultimately to the choice of either the Imperial System or the Metric System. No intermediate course was now possible.

Let them also remember that whether we would or not we must use the Metric System to an ever-increasing extent in this country because of our trade with other countries. On the other hand there was no compulsion for us to perpetuate the two systems, which we had been doing for many years past. He supposed that most of those present, either in science or industry or export trade, had had to work partly in the Metric System and partly in the English system, and they would have to continue to work in the two systems until they chose to abandon the less efficient. When one put it in that light he thought they would all agree that the English system was the less efficient and that sooner or later it must go. If it must go sooner or later, then the sooner the better in point of difficulties to be overcome.

In the existing postal system he supposed we had one of the best instances of world-wide international trade, and it was significant that when faced with the necessity of providing schedules of charges for the interchange of mail matter between the different nations of the world it was found necessary to adopt the Metric System as their basis. They had found that out over fifty years ago.

On this point he would read a single paragraph from a very excellent book on the 'Evolution of the Metric System' (by Messrs. Hallock & Wade, two American gentlemen), which was published in 1906: 'The interchange of mail by all the civilized countries of the world represents the most extensive use of a uniform system of weights and measures in the world, and has been carried on for many years without the slightest confusion or embarrassment. All mail matter transported between the United States and the fifty or more nations, signatories of the International Postal Convention, including the United States and Great Britain even, is weighed and paid for entirely by metric weight.'

There was another aspect of the subject which he would like members of the Institution to consider, viz., that the Metric System had been accepted as the international language of quantity by the scientists of the world, including our own and those of America. This meant that the scientists of America and the United Kingdom calculated and experimented in the Metric System and the manufacturers in these countries adhered to the old Imperial system. That being so, surely it was in our interest

to break down the artificial barrier which at present stood between the scientist in his laboratory and the industrialist in his workshop. It would certainly be an advantage that these two classes of brain should be in as close contact as possible.

There had been many exhortations and he might almost say warnings on the part of the Government and others since the War had broken out that a closer intimacy of contact between these two interdependent sections of the community was necessary for the future welfare of this country. Let us make it easy for them to co-operate and, by our adoption of the Metric System, provide one language of quantity for use throughout the world.

It was noteworthy that the author admitted he found the Metric System exceedingly useful in laboratory work, where he would not think of using any other system. Why admire the principles and value the utilities of the Metric System in laboratory work, and yet at the same time say, 'Let us maintain'—for ever, presumably—'the English system in our workshops.'

Another point was that he thought the author laid too much stress on the value of what he described as the accumulated knowledge stored in the library of an engineer. The engineering industry—and one might almost say all technical industries—continued to advance so rapidly that they all knew—many of them to their cost—that the literature which was standard even a few years ago was now quite out of date; it was obsolete, it described a practice which was no longer followed; and he thought, on consideration, it would be found that the value of such accumulated knowledge as is expressed in English weights and measures was not so great as the author would have them believe.

It was a sign of the times that many technical societies, engineering institutions, and technical journals had already adopted the practice of placing the metric equivalents alongside all English dimensions. It was an admission that data which they hoped would be of permanent use must be expressed in the Metric System, as otherwise they could not survive more than a few years.

On the question of education, the author had rather surprised him by saying that the scholars with whom he had come in contact had had the greatest difficulty in learning the Metric System. There was surely something wrong about that statement. That was one of the things he had wanted to discuss with the author. He thought he must have meant that some scholars rather disliked the conversion tables they had to learn. They did not learn merely the Metric System: they learnt that one mètre equals 39·37 in. instead of one mètre equals 100 centimètres, and it was the 39·37 in.

part of the table which terrified them, and not the 100 centimètres. In other words, it was a mixture of the systems which appalled them and not the Metric System itself.

On the question of interference with standards, the author apparently held the view that all existing standards were sacred. Standards were good and valuable, it was true, but it was wrong to assume that the standard of to-day was likely to be the standard of next year. For instance, our Engineering Standards Committee in their current annual report, recognizing the mutability of standards, had published this sentence:

Revision of reports. Reports have already been issued on many of the subjects referred to above, but it has always been recognized, from the inception of the movement, that, to avoid stereotyping present practice, revisions will from time to time be necessary. To meet this, the Main Committee has made a ruling that each Sectional Committee shall be afforded an opportunity of meeting at least once a year to consider whether any revisions in the Specifications and Reports drafted by it are desirable.

He would very much like to have the author's revised opinion upon the sacredness of standards after his consideration of that paragraph.

Then in regard to the 'practical man' argument, the taunt was thrown out against metric advocates that they were all scientists or dreamers or idealists and, in fact, anything but 'practical men.' If to be a practical man meant merely to be the 'horny-handed son of toil,' perhaps some of the metric advocates were not practical men; but if that designation included engineers of proved experience then he thought it must be admitted that many such practical men had long since realized the advantages of the Metric System.

For instance, only a few months ago—to quote a case in the author's own country—there was a symposium in New York of all the principal engineering institutions to consider the question of the Metric System, and he was informed they all, with the single exception of the representatives of the mechanical engineers, were in favour of the Metric System. Now, wherein did mechanical engineering differ, for instance, from electrical engineering to-day? Electrical engineers throughout the world were in favour of the Metric System, and it must be admitted that the electrical engineer, with his 20,000 kilowatt generators, and so forth, had to solve big mechanical engineering problems just the same as if he were designing and making steam engines. The modern electrical engineer must, of necessity, be a sound mechanical engineer.

Operations were of the same general character to-day in electrical engineering workshops as in mechanical engineering workshops, so that if electrical engineers said: 'We desire the adoption of the Metric System and would welcome it,' why did not mechanical engineers say the same thing?

The answer presumably was that the electrical industry was a modern industry, going back only about thirty years, and that at the outset, recognizing the advantages of the Metric System, it had adopted it as the best system available. If the Metric System had been available when mechanical engineers commenced their operations a century or so ago, he thought there was no doubt whatever that they also would have been metric advocates.

Many people feared that if an Act were passed to render the use of the Metric System compulsory instead of permissive, they would forthwith have to scrap all their valuable stocks of patterns, tools, jigs, gauges and the like. Such was certainly not intended, and such would not be the case, as was evident from the clause which was incorporated in the draft Metric Bill which was now being prepared by the Associated Chambers of Commerce on the lines of the instructions they had received from about 100 Chambers throughout the country. This draft Bill included this clause: 'Provided that nothing in this Act shall (*a*) affect the manufacture or use of any machinery, tool, pattern, sieve, template, or other article made by measures other than metric measures.' The passing of an Act on that basis would thus mean that while they would all be required to buy and sell in metric quantities, they would be at liberty to continue the use of existing weights and measures for manufacturing purposes until such time as they themselves chose to amend them.

No doubt manufacturers under the compulsion of selling their goods on the metric basis would, in course of time and at their own convenience, arrange to manufacture such goods to metric dimensions, but it was important to note that the above provision would have the effect of allowing each manufacturer to fix the length of his own transition period, and in that way unnecessary hardship would be avoided.

Engineers, for instance, knew that in the normal course of development of their industry the existing patterns at any given date became either worn out or obsolete in design within a fairly limited period. Surely it would be possible under that provision to continue those patterns in use for manufacturing purposes as long as they were commercially useful, and when it was necessary, either from development or because they were worn out, to replace

them, then they could be replaced by new ones based on the Metric System. There should be no particular hardship in that.

There was, however, a bigger question—the bigger national aspect of the question to-day. Everyone knew that in order to pay off the huge War debt we were now accumulating it would be necessary for us, after the War, to export enormously increased quantities of all kinds of British manufactured goods, and it was therefore our duty to examine, and if sound to adopt, every proposal put forward which would be even likely to assist our export trade.

Now, what had happened in the past in this connection? For years past we had turned a deaf ear to the entreaties of our Consuls and our commercial representatives abroad. Whoever had been abroad knew as well as he did that for years the peoples overseas had said to England: 'If you want to increase your trade with us you must reform your systems of coinage, weights and measures, and make it easy for your potential customers to come to you.' On that ground alone the Metric System had a most powerful claim upon us. Before he left that point he would like to urge that in contemplating such disturbance as the adoption of the Metric System would bring in its train, let us not regard it as something nauseous which would always be a trouble to us. When it was done we should ourselves reap the benefits and our children would be rid of the hampering influences under which we now suffer.

He would like to say a word or two in regard to the positions of America and the United Kingdom. It was frequently urged that so long as such nations as the British Empire and the United States stood aloof there was not much hope of the Metric System being universally adopted. Why had not America adopted the Metric System in the past? He submitted it was primarily because the demand for her goods was essentially a domestic demand. Until quite recently they all knew that America had relatively no export trade. But as soon as she tackled the export problem she immediately set up the agitation: 'Oh, we must have the Metric System if we are going to make a bid for the South American trade and that of the other metric countries.' As soon as they set out to become exporters they appreciated the benefits of the Metric System. Now, our country was essentially an exporting nation; we must export or we could not live; therefore the arguments in favour of Great Britain being the first to make the change were in his opinion overwhelming. If we made the change in our own interests America would certainly follow and we should have true uniformity.

The closing note of the author's paper says: 'In conclusion, I desire to make it quite clear that my arguments in this paper are not directed against the Metric System, but rather against the propaganda for the compulsory adoption of it.' He had dealt very fully with that point in the Lecture to which the President had done him the honour to refer, and he would read one paragraph:

'A favourite argument against our compulsory adoption of the Metric System is that by merely prolonging the present permissive use of the Metric System side by side with our existing British Imperial system the better system would ultimately survive. A similar argument is put forth to the effect that those who desire the introduction of the Metric System should lead the way by conducting their own business solely in that system. I submit that any such voluntary piecemeal adoption cannot be expected, as the pioneers would thereby penalize themselves by throwing themselves out of touch with their neighbours. The position is analogous to that of the Daylight Saving reform. No benefit could be derived from that reform until it was made compulsory, for had any enthusiast adopted the principle before its general adoption he would have found himself at his office or works (say) an hour before he could communicate with his clients, and when, at the end of the day his clients desired to communicate with him, they would have found he had already gone home, having completed his day's work.'

The advocates of that reform preached in vain for years the benefits of it. Either from apathy or sluggishness, even those who did not oppose it did not ask for it, and we should have gone without it altogether had it not been for the intervention of the War, which forced us to realize its many advantages, and we all now said: 'Why didn't we adopt it years ago?' Why not, therefore, now throw off the shackles by which we were bound in the matter of weights and measures? The superiority of the Metric System had been demonstrated over and over again.

In conclusion, let them bear in mind the words of the Rt. Hon. A. J. Balfour, M.P., who, replying to a deputation in 1895, said: 'Upon the merits of the case I think there can be no doubt whatever that the judgment of the whole civilized world, not excluding countries which still adhere to the antiquated systems under which we suffer, has long decided that the Metric System is the only rational system.'

The War had quickened in them all a livelier appreciation of the defects in their national equipment and now—while public opinion was in a plastic condition—was the time to give effect to the overdue reforms which the author apparently desired to oppose.

The President requested the Secretary to read the following letter from Mr. Edward Hooper:

Would you please express to the President my regret that I find myself unable to be present to-night at the discussion of the paper by W. R. Ingalls on the Metric System, owing to an unexpected call for police duty.

It was my intention to support as far as possible the arguments so ably set out by Mr. Ingalls, although I am afraid there is but little that one can add to what has been said and written by so many writers during the past 10 or 12 years against the compulsory adoption of the Metric System in Great Britain and the United States.

There is one point, however, that should perhaps be emphasized. In France, after various enactments, a Bill or 'projet' was passed in July, 1837, which came into force on 1st January, 1840, whereby the possession of weights and measures other than those of the Metric System was made a penal offence; further, the use of any of the old names of units was forbidden. Yet in 1906, or nearly 70 years later, the French Minister of Commerce felt himself obliged to issue a circular to the various French Chambers of Commerce requesting them to use their influence upon merchants and their customers to induce them to abandon their use of the forbidden weights and measures.

Moreover, the Metric System was legalized in U.S.A. in May, 1866, but we do not find that it has been adopted to any great extent.

I altogether fail to see how the Mining and Metallurgical Industries would be greatly benefited by the compulsory adoption of the Metric System, but I do plainly recognize that manufacturers of the goods which are used by these industries would be put to an enormous expenditure, and that a large part of this expenditure would have to be borne by the industries which are represented by the Institution.

Prof. Henry Louis said he was very pleased to have an opportunity of being present and taking part in the discussion. It was a subject which had been before him for a great many years and he had taken a great deal of interest in it. It was perhaps fair to say at the outset that all his predilections were in favour of the Metric System to begin with. He, like the author of the paper, could visualize the gramme better than the grain, the litre better than the gallon, and even the kilomètre better than the mile. Like all scientific men he had had to work with the Metric System. He had also had a great deal of work to do on the Continent of Europe and in countries using the Metric System, and had constantly to use it himself in surveying, and in taking out quantities and so

forth. Nevertheless he had quite come to the view that the attitude taken up by the author was the correct one.

He wanted to put the point clearly as he saw it, in this way: They were not discussing the question of the Metric System versus the Imperial System, but the question of the metric unit versus the Imperial unit. He was far more decidedly a decimalist than Mr. Sulman had shown himself to be. He was a thorough believer in the use of a decimal system, but as the author had pointed out, the decimal system and the Metric System were two very different things. It was the easiest thing in the world to poke fun at our chaotic collection of weights and measures.

The fact that we used those weights and measures did not imply that the system was a good one; everyone was perfectly ready to admit that our present system was a bad one; but he did maintain that our units were for practical purposes the most useful we could have. It was perfectly easy, as had been pointed out, to decimalize the foot, or the inch, or the mile, or the ton, or any other unit that we pleased.

The author had been rather a bold man in bringing that subject before the Institution of Mining and Metallurgy, because he thought that of all branches of engineering probably mining and metallurgical engineers would be more likely to give preference to the Metric System than workers in any other branch of engineering. And the reason, as he saw it, was that the mining and metallurgical engineer was more concerned with weights than with measures, whereas the mechanical engineer and the civil engineer were more concerned with measures than with weights.

The advantages of the Metric System were distinctly more marked when one came to deal with weights than when one dealt with measures, and the reason probably was that the measurement of length was the only direct method of measurement that we possessed. Whenever one came to measure any other quantities, time, mass, volume, weight, one always came down finally to linear measurements. If one wanted to measure the length of the table one took out a foot rule. One could not do that with anything else; one could not see how many pounds there were in a ton by an analogous method of measurement.

Determination of length by direct measurement being so obviously a matter of direct reference to a unit, was one of the main reasons why the mechanical engineer was so strongly in favour of adhering to our present units.

Surely the argument that our present system was fundamentally bad, because it had not a scientific basis, was incorrect. The nature

of the basis had little or nothing to do with the use of the units derived from it. But by a very curious coincidence, the scientific basis of the Imperial system of measurement was almost identical with the scientific basis of the Metric System. It was quite true that ours was derived from the length of a pendulum beating seconds, while the French system was derived from a more or less correct measurement of an arc of the meridian, but it was nevertheless a curious fact that both had a basis so close to each other (39·139 in. and 39·37 in. respectively), and that both were strictly scientific.

Although he had had to do a good deal in the way of taking out quantities in the metric methods, he did not see any great advantage in it over the English system. He agreed that if he had to sit down and figure out the number of tons in so many cubic feet by long multiplication, he would probably prefer the Metric System, but surely every engineer used a slide rule or a table of logarithms, and the amount of additional work which was involved was then practically negligible.

A great point was made by the advocates of the Metric System of the advantage of uniformity. He could not help asking himself, was there any such advantage? One of the very few mistakes of fact which the author made in his paper was the statement that we in this country had only one ton. He knew four or five, and probably other people in the room could more than double that number. Everyone knew that a ton of explosives was 2000 lb.; a ton of copper ore was 21 cwt.; a ton of ironstone was 2400 lb.; a miner's ton of iron ore was 2600 lb., and so on. Why did we keep them all? Simply because it was not found inconvenient. It was perfectly easy for any of the users of such measures to abandon those tons; the law of the land enforced the statute ton, nevertheless everybody kept on using the others also. Why? Because they did not find any inconvenience from it. On the contrary, they found it useful to keep them. Surely that showed that the much vaunted uniformity had not the importance which some people attached to it.

People in metric countries did not believe in their own alleged uniformity. Not many years ago he had been called in to advise with regard to a water-power scheme, which was drawn up in one metric country and the tender was being placed in another metric country: in the specification the diameters of the water-pipes were quoted in English inches, and that specification went from one metric country to another. When one saw things like that, one began to ask oneself: Is there really any such enormous importance

in uniformity of measures all round? He saw very little more importance, if any, in the argument that the scientist and the industrial man could use the same weights and measures if we adopted the Metric System. The industrialist was not going to worry about milligrammes, which had however to be used in the laboratory. It was perfectly easy for a man to make his analysis in milligrammes and to translate his figures into tons, and it did not require any very great mental effort.

He did not think Mr. Allcock was quite fair to the Engineering Standards Committee in his reference to their arrangements for revising standards. The Engineering Standards Committee did insist upon a revision of standards from time to time, but they had never insisted upon a revision of units, and, after all, units were the things they had to argue about.

People who agreed with his own line of argument maintained that the foot was a handier standard than the mètre, and that the lb. was a handier standard than the kilogramme. Everywhere in France vegetables and fruit were quoted at so many 'sous la livre'; they stuck to the old term because they found it was a handier unit. Why should we displace our handier unit by a unit which people in metric countries themselves found to be less handy and less convenient? He thought the reasons why the mechanical engineer objected to alter his standards were obvious enough. It was also obvious why the electrical engineer and the aeroplane engineer were willing to adopt metric standards.

If ours were a new industrial nation starting in business to-day he would not argue as he was doing; he would certainly advocate the adoption of the Metric System. But this was not a new industrial country; it was an old-established one, with centuries of industrial experience behind it, and that experience was based upon the units with which we were all familiar. Any change of those units would lead us into expenses that he did not dare to think of. Let them take the commonest example possible. He supposed there must be in Great Britain at least 5,000,000 gas meters, measuring gas by the cubic foot: how much would it cost to change all those gas meters to record in the Metric System, and how many rows and arguments would each individual householder have with the gas companies (which gave us trouble enough as it was) if he had to pay for his gas as measured by the Metric System.

He was not in the least convinced by Mr. Allcock's argument that we should not need to scrap our patterns and jigs and gauges and so forth. We should have to. A man could not sell things in metric measure and make them by his present patterns. If he had

to sell things in millimètres he would obviously have to manufacture by that unit, and all that enormous quantity of material, worth no one knows how many millions of pounds, would have to go by the board. It appeared to him inevitable that, if we were going to adopt the Metric System, we would have to face quite gigantic expenditure. Of course the very idea of working upon a mixed system would be absolutely intolerable. Think of any of them having a broken rising main and sending for pipes in a hurry and finding they would not fit because the pipes bought had been gauged by millimètres while the old pipes had been gauged in inches. It was impossible to predict how many hundreds of thousands of pounds every one little thing like that might cost.

His view was quite clear on the point, that an old-established country, which had led the way in industries for so many centuries, was far wiser to keep on as it was; it was far better to 'bear those ills we have than fly to others that we know not of.' We knew our difficulties at present. We had become the first industrial nation of the world by sticking to those old, well tried, practical standards. Why should we run any risks by now changing these standards? There was no evidence whatever that our foreign trade would be improved by working in the Metric System, and as for the internal economics of the country, no one knew what would happen. What kind of bricks was one going to put in on a Metric System to repair a 9 in. wall?

We had all our old standards of feet and inches in our minds in our every-day work, in our legislation, on every side of us, and the dangers and difficulties of changing those would to his mind be enormous.

He emphatically agreed with what had been said: by all means, decimalize as far as possible; certainly let us adopt the ton of 2000 lb.; let us adopt a definite unit of a mile of 5000 ft., and so on throughout the whole gamut. He was a thorough believer in decimalization; he was a thorough believer in the decimal system as far as it was a decimal system; his attack was wholly and solely upon the proposed compulsory change of units.

Dr. Frank L. Teed thought that there was a great deal of unanimity in the meeting. He thought that if the proposition were put that the Metric System was more suitable, if we were starting afresh, than the present system, it would be voted for unanimously. He thought also that if another proposition were put to the meeting, that the people engaged in trade would incur considerable expense in passing from the English system to the Metric System it would also be agreed to practically unanimously.

But of course the question was what amount of expenditure would be involved.

He wished Mr. Sulman had been able to remain, because Mr. Sulman rather attacked not only the Metric System but also the people who believed in it. There was one expression which he had taken down: Mr. Sulman said that the Metric System was not more scientific than our own. He thought Mr. Sulman on reconsideration would admit it was more scientific, because there was a correlation between weights and measures which did not obtain in the English system. Taking the example of the cub. ft. and gal., which one could not get away from: there was no simple connection between the two. The recommendation of the Committee of the Institution of Mining and Metallurgy on the question of the miners' inch was that it should be expressed in cub. ft. or gal.; they had not made up their mind.

There was one thing on which the advocates of our present system—he was not sure about Prof. Louis, but those he had spoken to privately—were at one with the people who believed in the Metric System: the people who advocated the Metric System were anxious to abolish all the English standards, and all those he had spoken to privately who advocated maintaining the present English system were in favour of abolishing one standard or two standards. If he could go round the room and get all the Imperial System men to write on a card what they would abolish, he was sure by the time he had made the round everything would be abolished.

Another argument which had been used, both in the paper and by Mr. Sulman, was first of all that the Metric System did not preclude one from using decimals in the Imperial System. Very good. Everybody was agreed about that. But later in the paper, and in Mr. Sulman's speech also, it was said that the question of the 'damned dot' smashed the decimal system because people were bound to put the dot in the wrong place. Now they could not have it both ways. If decimals were a good thing, the Metric System was a good thing; if decimals were a bad thing they must not be imported into the Imperial System.

The mischief of the Imperial System was that it was not one system but many systems. They had talked about weights a good deal. The only thing common in all our weights was the grain. The grain was common to Troy Weight and to Avoirdupois Weight. We had that beautiful ounce Avoirdupois containing 437½ grains—a beautiful figure to divide by, and the Troy ounce, as everyone knew, was 480 grains.

Taking our system of length, the foot was the commonly accepted standard length, but let them ask a surveyor what his system of length was. It had been brought to his mind by buying an ordinary tape to measure distances in feet. On the other side he found it was marked in links. That had not been bought fifty years ago. It was bought about fifty days ago; it was a modern surveyor's measuring tape. He did not think it was dated, but it was quite new. He found by calculation that the link was not quite eight inches; it was 7·92 in. It was a beautiful standard! The reasons why links and chains were introduced—he expected the members knew it better than he did—was that there was no simple connection between feet and acres, but by introducing a chain and dividing it up into links, and so on, one got a better connection between linear and square measure.

To revert for a moment to the recommendation of the Committee of the Institution, they recommend that the value of gold ore should not be stated in oz. per ton but in money value, taking the value of gold as 85*s*. per Troy oz., so we still had our two ounces.

Prof. Louis had remarked that one could decimalize any unit. Of course one could decimalize any linear measurement, the inch, the foot or the mile, but when one had done it and wanted to convert one into the other there was the same old trouble as if one had not decimalized at all; one had to remember that 12 in. made a foot, and that—he had forgotten how many feet made a mile, but three times 1760.

The recommendation of the Institution was that the ton should be a ton of 2000 lb., and for metalliferous mines he had no doubt that was a most excellent recommendation, and he had no doubt that coal merchants would also welcome it. But he did not think that it was likely to be adopted by the man in the street who had to buy the coal. If one wanted a ton which was not quite the same as the 2240 lb., why not adopt the metric ton which he had just worked out and found it came to 2204·6 lb.—very close to the 2240. So that there was not much difference between the metric ton and the old English ton.

Prof. Louis also seemed to think that converting a measure of capacity into weight and so on was a mere nothing, because one could use a slide rule or a book of logarithms. They wanted to avoid that, which could be done by adopting the Metric System.

Mr. R. Gilman Brown* said he had no intention of saying anything, in fact at the moment he scarcely knew what they were

* See additional contribution to discussion by Mr. R. Gilman Brown in 'Contributed Remarks.'

discussing. He had been surprised to find that the proposed Bill, from which their distinguished guest had read a clause, only provided for obligatory use in buying and selling. Well, it might be that it was possible to go on with both systems, with some inconvenience, using one system in the shop and one in the market, and it might be that it would result, as Mr. Allcock had said, in the Metric System gradually ousting the other. But they must all agree that it would take some time, and to his mind the most serious feature of the whole question was its inopportuneness. He did not want to touch on the question of what was the ideally best system, but he did wish to say that we were coming into great periods of reconstruction. Many things were absolutely inevitable: they must be undertaken. Then why load our shoulders with a thing which was not inevitable, and which to a large number of people showed no great advantage, if any?

The question of standards, of jigs and templates and so on, had been referred to. He had not the remotest idea of what the value of those things in this country came to, but it possibly amounted to more than half the present War debt. Even if the change were going to come slowly, as was proposed in what had been quoted, each year must bear its share of the burden. Suppose it came in ten years: did we want to saddle ourselves with 100 millions extra expenditure for the next ten years?

Suppose it came in twenty years: fifty millions was quite a large sum. It seemed most serious to take that money out of capital. They would be scrapping good plant by changing the standard, and would be depriving themselves of that capital which would otherwise go into constructive work. He thought it would take a very strong advocate of the Metric System to claim that the increased advantage we might have by dealing with metric countries was going to pay interest on that capital sum.

Mr. Walter McDermott said he did not think it was right to accuse mechanical and mining engineers, here and in America, of apathy or of unwillingness to investigate the matter. It had been investigated on a number of occasions, and the great difficulty was that there was not a sufficient majority in favour of the Metric System to overcome the natural objections to making any national change.

Many of the arguments in favour of the Metric System seemed to him to come from the theoretical rather than the practical side. With regard to the immediate gain which we might get in England, for instance, in foreign trade, he did not know that our Consuls abroad were the best authorities on the subject. They had not been

so in the past. They had not been like the German Consuls, who had been really interested in commerce. If we went to the Germans, as we had been advised to do, for information how to get trade, we should have to adopt more than the Metric System in order to succeed; we should want their State aid for industry and shipping; and have to give liberal terms to the many purchasers who attached more importance to low prices, and long credits, than to the beauties of the Metric System. Many of our greatest admirers of German science, education, and intelligence, were those who would not approve of any practical aid from the State, for industry.

The manufacturers who were enterprising in bidding for foreign trade (and he had had some experience in metric countries for a great many years) found no insuperable difficulty in meeting the requirements of their customers in the matter of metric measurements in their catalogues, and their drawings, and correspondence; so that, although the advantage of uniformity was undoubtedly great, it had not been proved that we were industrially suffering so much from the mere lack of this uniformity as to make that in itself an exceedingly strong national argument. It could be got over by putting the special trouble on the people who were doing the export trade, and benefiting by it, which did not upset the whole of the rest of the nation who were not so much interested in it.

Mr. H. M. Morgans said that the paper contained an admission both stated and implied that our systems of weights and measures were bad, and it acknowledged that the Metric System was better. The author conceded that for new arts and businesses such as aeronautical plant and Diesel engines the Metric System was rightly used in the United States. The author made a great point of the mental images which we conjure up as part of our being.

The other day a mining engineer was telling him that he had an in-come of water of 5,000,000 gal. per day. That, to the speaker's mind, did not convey much. If the quantity had been given as 208,330 gal. per hour he could not visualize it, but if stated as 3472 gal. per min., he would have got a fair idea of the quantity, could give a rough guess as to the size of a pump to handle it, and could say what sort of a stream it would make. That is the way in which he visualized quantities of water.

A Frenchman thought of the same thing in cub. m. per min., and it would be useless to talk to him of gallons per 24 hours. The Cornishman and the Scot thought of depths of shafts in fathoms, whereas he always thought of them in yards, and other people

thought of them in feet. The jargon of the motor business in this country was metric; cylinder and tyre sizes were quoted in metric dimensions. The point he was making was that the particular unit in which things were visualized was entirely independent of the system. It was the result of habits, and those habits could change.

The author combated the much bruited tale of the widespread use of the Metric System by pointing to the importance of Great Britain and her Colonies, the United States and Russia, in balancing up the world's weights and measures. He did not think the author was fair there, because the comparison was really between a substantial portion of the population of the world which used a standard metric system with at any rate a great measure of uniformity, and the rest (albeit a larger portion) who were using a terrible jumble of weights and measures.

In non-metric countries all the men of science used the Metric System, and there were groups here and there who were using the Metric System for industrial purposes.

The Metric System was a simple one. He had in his hand a little steel rule made in America. It was a millimètre thick, a centimètre wide, a decimètre long; its contents made a cubic centimètre and its weight in grammes was the specific gravity of the material. That was the simple and convenient basis of the Metric System.

Drawings in metric measurements were very easy to make and read. There was no question of mixing up feet and inches. There were no decimal points; everything was in millimètres.

He saw drawbacks in the Metric System. The number of figures in a long calculation grew rapidly, necessitating recourse to the slide rule or to approximate methods of multiplication and division, taking care to achieve the necessary degree of accuracy. Simple factors disappeared.

The value of the paper to his mind was that it pointed out the great difficulties there would be in changing over to the Metric System. It was not an argument against the need for the change to the Metric System, but it did call for care in instituting the change and for a necessary period of transition; it might be ten years or it might be longer.

It seemed to him that in changing over to the Metric System the business should be in the hands of some standing Committee on which all interests would be represented, and which would fix dates for the stages—"On such and such a date you must make no new designs using the old system"; "On such and such a date you must scrap all your old patterns" which by that later time will be

worn out and useless), and 'At such and such a time later on still you must have effected the complete change.'

He had no doubt that the change was necessary, and would have to be undertaken. It was difficult to undertake it now, but it would be ten times more difficult to undertake it in a few years' time. When adopting the Metric System any defects or difficulties that had shown themselves in the long history of the Metric System on the Continent could be corrected.

Mr. H. F. Marriott said that the remarks of the previous speakers indicated that the keynote of the problem was 'simplicity.' It was obvious that there were so many opponents to the wholesale change to the Metric System, that it could not be imposed on the country compulsorily at the present time. On the other hand he quite agreed with the speakers who had advocated it that the ideal to look forward to in the world was to have a uniform system. Therefore, if we commenced to-day to simplify our own systems we would advance towards that ideal whilst causing a minimum of dislocation.

He hoped he would be in order in discussing the money question. That was the foundation of all changes. The most useful of the recent proposals appeared to be that which was based on the florin as the unit of English money. In this case in order to decimalize our coinage there was only one coin to alter, namely, the penny. This alteration involved a reduction of 4% in the value of the penny. At the present time this would cause very slight inconvenience because the penny to-day had no standard value as reflecting the value of anything in the market.

This particular drawback to change had gone for the moment. With the florin as unity and 25 pence to the florin instead of 24, and 100 farthings to the florin instead of 96, and the elimination of the unnecessary half-crown, our whole system of coinage would be decimalized. The sovereign, the best coin of commerce throughout the world, would stay, and the interchange of money with other systems would be greatly simplified.

Coming next to weights, for simplicity we required the standardization of one unit to which the standard units of other systems could be referred. The author of the paper had stated that he wished to keep the consideration of the decimal system apart from the Metric System, and he did not agree that this was possible, because he considered that the present discussion on the Metric System only arose on account of its decimal qualities. He assumed that the advocates of the Metric System only put it forward because it would introduce the decimal system.

With the lb. as our primary unit, and a ton of 2000 lb., a very large proportion of our requirements would be met within the decimal system. It would be inadvisable to attempt to change the oz., or any of the smaller current units, but any community that kept their records in any other unit of their selection, should be compelled to keep to that unit and its decimals, so that a change into the legal equivalent in lb. could be made by one factor. This would greatly simplify interchange with other countries which also had decimal systems.

With regard to the measurement of length, the foot was probably just as good a unit of length as the mètre; in fact in many ways it was better, as the requirements for small measurements were more varied than for the more comprehensive units. He did not agree with Prof. Louis that the mile could be brought into line by altering it to 5000 ft.; the railway companies would have something to say on the question of cost. The records involving the use of the mile and fractions of a mile would not interfere unduly with those for which the foot was most suitable, but any intermediate measurement should be abolished. The mechanical engineers could retain the inch and still be progressive so long as they used decimals, because the transference to the legal standard would then only require the application of one factor.

It seemed to him that progress in this movement would be attained more rapidly if, instead of dividing themselves into two camps with the mètre as the basis of discussion, they would steer a middle course and commence a campaign to reduce the number of our units, choosing one primary unit in each case as the link between our and other systems.

That would go a long way towards putting the next generation in a position to choose one universal system should they desire it.

Prof. S. J. Truscott said his experience had been rather unique, inasmuch as he had lived for many years in a country where the English milestones had been taken down and kilomètres put up. That was on the island of Sumatra in the Province of Benkoelen, which was formerly British but afterwards became Dutch. He had worked there on a mine where the metric system was adopted and where its conveniences were manifest. On the machinery plans, instead of having, for instance, 4 ft. 8½ in., they had 1435 millimètres. It was not even necessary to state that they were millimètres because nothing but millimètres were on the plan.

The mining plans also were made to metric measurement, and the convenience of that was obvious. They were drawn to such a scale as 1 in 500 or 1 in 1000, instead of 40 ft. to the inch, which

was 1 in 480, so that both the foot rule and the mètre rule could be used upon the plans equally conveniently.

When the Institution of Mining and Metallurgy sent out the circular to its members, he had replied in favour of the adoption of the Metric System. But since that time he had had opportunities of reviewing the position, and what he thought now was that it was not so much our principal units which were at fault as the use of so many secondary units. In collieries, for instance, they purchased hoisting ropes by the fathom to work in shafts so many yards deep, when the unit of length was the foot. If the fathom and yard were given up except in very special cases a good deal of confusion would cease. The inch was the twelfth part of the foot, it was true, but within a certain range it was a most useful unit. At the particular mine to which he had referred the workshop staff was entirely German, and in that shop these men themselves used the inch, they spoke of bars of iron in inches; so that this unit was largely used in Germany still, probably because Germany had adopted the Whitworth standard of threads.

He did not think there was much wrong with our units. In the ordinary mechanical calculation there were only three units, the foot, the lb., and the second. In the Metric System there were two systems really: there was the centimètre–gramme–second system, which was that of the absolute units, and there was the mètre–kilogramme system, employing gravitation units. It might be said that there was no difference between those two systems, but there was. With the absolute units the mass was equal to weight; in the gravitation system mass was not equal to weight but to weight divided by the acceleration of gravity. That was a complication which was, perhaps, small, but it showed that even in the Metric System there was not perfect uniformity.

Mr. Edward C. Barton wished to draw attention to one point which might be emphasized on the metric side. Mr. Allcock had referred to it; he had read a little paragraph out of the Bill with regard to non-scrapping. That was a clause which prevented the Act from operating in the direction of enforcing the scrapping of machinery.

The curious part of it was that the scrapping bogey had been repeated by many of the speakers; it had been said, indeed, that half the cost of this War would be incurred by the enormous scrapping of machinery.

The last speaker had given them a most interesting piece of information, viz., that even in Germany at the present day the inch was still in use, and that there were machines in use on that

standard. It was extraordinary to hear that on the one hand, and on the other to hear that all that gigantic scrapping which had been referred to must take place as the immediate result, or as the ultimate result, of ten or fifteen years' work at a cost of 100 millions per year.

He would like to draw attention to the fact that some saving would also be made. He was recently in Birmingham and called on a tool maker, expecting to find the deadliest enemy that the Metric System could have, but was much astonished when the tool maker took him round the establishment and pointed out duplicate stocks in the Metric and in the English system, saying, 'I do not care whether it is English or metric, but for Heaven's sake abolish one of them! We have to keep stocks of these things, and at 3s. odd a lb. for steel it is like storing golden sovereigns.' There was something to be saved by our adoption of the Metric System. As to the change it would take place gradually. It was still taking place in other metric countries slowly. That slowness was urged as a crime against the Metric System. As one of the speakers had said, they could not have it both ways; it could not be made a crime against the Metric System that the change was slow, and at the same time a crime that it was going to be rapid. If we adopted it to-day it would be many years before the change would be completed, and he did not think that there would be any money lost by anybody.

The President said he would like to thank all the speakers who had assisted in the discussion. He felt that, as President of the Institution, he personally must take an impartial position and express no view. He had very nearly interrupted their friend, Mr. Humphrey Morgans, when he was speaking about visualizing. For years he had been in the habit of adopting the cricket pitch as his method of estimating distance. He had got that into his head as a schoolboy, and had used it ever since.

CONTRIBUTED REMARKS.

Mr. R. Gilman Brown: I should like to add a few words to my remarks. My whole argument is, that no unnecessary burden should be laid upon us during the early years of reconstruction, and whether the burden be one of thousands or millions, the principle is the same. Nor does it matter whether the off-hand figures I hazarded are unreasonable or not. I am not, however, prepared to admit that they are unreasonable, for the ramifications

of a change of this kind cannot be foreseen by anyone. Moreover, its burden will not be financial alone, and attention will everywhere be distracted from pressing constructive work not only in the shop, but in the office and in the study.

We cannot get away from the fact that the change would be a burden. Is it then necessary? We are told that it will enable us to convert with facility from cubic measures to those of capacity—granted; that the Troy ounce will not then be confused with the Avoirdupois ounce—granted; that we shall have only one ton—again granted; but what fraction of 1 % of the daily myriads of measurements do these operations represent, and is anyone bold enough to say that this fractional per cent. constitutes a necessity for the change?

It is the practical side of the matter that concerns us, and not the ideal; we can even afford to grant that familiarity with the Metric System may, contrary to the belief of many of us, bring all the benefits promised, and we are still a long way from any proof of necessity.

Finally, can we even accept the claim of advantage from the present adoption of the Metric System. Oliver Wendell Holmes once observed that a man's brain could be developed to almost any extent if we began early enough, but, he added, that we might have to go back half a dozen generations to do it. That is the answer to the question of advantage; the change is advocated as a reconstruction measure, but for that it is years too late. At a juncture where we shall need all our skill we are asked to use unfamiliar tools; I can conceive of no more efficacious way of handicapping our post-war exertions.

FURTHER CONTRIBUTED REMARKS

ON

'The Economic Geology of the Insizwa District.'

By W. H. Goodchild, *Member*.

Professor J. W. Gregory: Mr. Goodchild's suggestive paper is an excellent example of how a careful genetic study may point out future lines of working metalliferous material which at present cannot be profitably mined. One special interest in his paper is the comparison between the Insizwa and Sudbury fields; in both, the ores occur on the underside of a sheet of basic igneous rock that has been described as laccolitic, though in neither case is that structure certain.

Mr. Goodchild's evidence from Insizwa appears at first sight to support the theory which has been so strongly advocated for Sudbury, that the ores were due first to the sinking of the sulphides into the basal layer of a sheet of molten basic rock, and second to their matte-like segregation in that layer into orebodies. The striking resemblances established by Mr. Goodchild between the Insizwa and Sudbury ores seem, however, to strengthen the weighty arguments against that theory for the Sudbury ores.

The evidence at Insizwa seems inconsistent with the origin of its ores by magmatic segregation, as that theory is generally represented. That the basal sheet of picrite may be due to gravitational differentiation is quite likely. It would be a large scale example of the process which, as shown by Mr. Tyrrell, occasioned the differences between the successive layers of the Lugar sill. But that the mineralization of the picrite was due to the same cause is doubtful. The ores, as Mr. Goodchild has shown, are not limited to picrite, but occur also in the veins of acid rock and also in the dolerite dykes which are even younger than the consolidation of the gabbro, as they cut across it.

Moreover, the sulphides are not in the form that would be expected in matte-like segregations, for the bulk of it occurs as finely disseminated particles and not aggregated into masses. The sulphides are sometimes in pellets: but both these and the disseminated particles occur in the sediments as well as in the igneous rocks. The ore, again, sometimes occurs as branching veins of solid sulphides, which are as much as 100 ft. long by 2 ft. thick and pass from the igneous rock into the sediments. Further, the sequence of minerals shows that the sulphides were not formed in the first stage of the consolidation of the rock, for Mr. Goodchild describes them as occurring interstitially and moulded on the silicates (p. 16).

Hence, it is clear that the Insizwa ores are not primary magmatic segregations. The chief argument for their igneous origin is that, as Mr. Goodchild points out, all the four different kinds of ore at Insizwa occur beside the lower contact of the intrusive gabbros. This fact is suggestive that the ores were perhaps collected there by liquation and subsequently re-arranged. If so the ores were segregated by igneous action and dispersed by secondary processes—the reverse of the general rule. The hypothesis is, however, opposed by two considerations, the dissemination of most of the ore in minute particles, and Mr. Goodchild's record that the average copper-nickel ratio in the ore of the fissure veins is the same as that in the picrite. If the particles in the picrite were primary and igneous, and the vein sulphides secondary and aqueous and later than the dolerite, some difference would be expected in the relative proportions of the metals in the different ores.

The restriction of the mineralization to the basal contact of the gabbro series may be explained by other processes than gravitational differentiation. After the consolidation of the gabbro its magmatic waters would have penetrated far into the overlying rocks and escaped to the surface, whereas the water that entered the underlying rocks would be confined to the contact zone. This difference in penetration would have resulted from two main factors—(1) the intrusion would probably have ruptured the uplifted rocks and compressed those below it, (2) the gas pressure would have helped the movement of the ascending water above the intrusion, and opposed that of the descending water below it. Hence, if magmatic water from the intrusive mass had deposited the ores, they would have been concentrated below and widely dispersed above. When the dolerite was intruded it would have been liable to some mineralization where it cooled in contact with the ore zone by the solution and re-deposition of the ores.

In these respects the Insizwa ores agree with those of Sudbury; the ores there occur near the base of a sheet of norite and are distributed so irregularly, and in such forms, that liquation is not a satisfactory explanation of their distribution. The microscopic study of the ores shows that the Sudbury sulphides, like those at Insizwa, were not the first minerals to solidify, but that they were formed after the consolidation of the rock, as they are interstitial to the ruptured silicates and form a cement to the brecciated norite.

Mr. Goodchild's paper bears on many other interesting problems of both economic and structural geology. For instance, the presence of the platinum in this part of South Africa is another of the features in common, it is probably more than a coincidence, between South African and Russian geology.

AUTHOR'S REPLY TO DISCUSSION

ON

'The Wet Assay of Tin Concentrate.'

By H. W. Hutchin, *Member.*

Mr. H. W. Hutchin : My preference is towards a collective reply based on the main points of the discussion rather than a detailed reply to each individual. Whilst preparation errors were accepted in principle, there was evidence of scepticism as to the extent.

Mr. Bannister, in discussing this matter, begins with a criticism of the procedure in the muller and slab experiment, but at a later stage confesses that 'very serious contamination could occur on a muller and slab.' The procedure was dictated by the fact that the muller and slab had been in disuse for a considerable period except as a mixer. To those familiar with the effect of the moist Cornish air on iron (to say nothing of an added acidity from the laboratory) the condition of the apparatus and the need for caution may be imagined. Under such conditions the obvious procedure was to accept the plate as clean when two consecutive preparations gave concordant assays. The figures given by him for quartz ground in an iron mortar are interesting and distinctly valuable: moreover they do not conflict with the special steel mortar experiment in the paper: but why stop at -90?

Many workers using the Pearce method practise much finer grinding, to say nothing of the requirements of the Beringer method. There is every indication in his figures to -90, that if the series had been extended to, say, -200 and beyond they would have shown very many sources of error. I should not share his faith in the efficacy of the magnet for removing iron from such finely powdered material. The difference between Mr. Bannister and myself is in our conception of what is fine grinding.

With respect to the material floured in the steel mortar and reported at 1·6 % iron and blank test 'very little,' the very little was under 2 % from agate powdered material.

Mr. Trewartha-James in comments on the statement made on p. 7 ignores the outstanding feature, viz., that the unpowdered samples invariably returned higher assays than the Wedgwood powdered. There was no intention on my part to consider them as approaching absolute values: it was stated that they were taken from preliminary investigations to which may now be added the

fact that the series of six assays on p. 6 was put through to test the general conclusion arrived at from the preliminary investigation.

The examples No. VII which he quotes do not need the introduction of sampling and assay errors: they may be explained solely on preparation errors. I have stated on p. 5: 'The worker obtains in duplicate assays a delightful concordance without a suspicion that errors of 1, 2 or 3% may have been introduced before the charges had been weighed out.' The worker would not obtain that concordance if the duplicates were of separately prepared portions. The longer the period of rubbing the lower the assay will be. In an ordinary way two separate portions prepared for assay may approximate to the same value.

Surely it is better to eliminate an unsound procedure first; confidence is restored, 'sampling and assay errors' then receive due consideration. The logging of the pestles was instituted in the hope of corroborative evidence, not with any hope of exact mathematical calculations. The preparation of a sample for assay is a procedure which does not lend itself readily to mathematical calculations. It is one of gradual reduction, the final grinding being performed on as small a quantity as would meet the requirements. So, too, the mortars were far too heavy to be weighed with any pretension to accuracy by the balances at hand, but it is my conviction that the loss in weight of the mortar is as great as that of the pestle. That conviction is strengthened by a subsequent inspection of the mechanical muller and slab in use at the Bessemer Laboratory.

Mr. Picard's statement:—'So far as the record went it showed that grinding on the plate yielded a higher instead of a lower result'—is obviously not in harmony with the facts. The remainder of his remarks on the muller and slab experiment have been dealt with in answering points raised by Mr. Bannister. I am by no means inimical to the Pearce assay: my attitude towards it is rather in the direction of working out conditions whereby a large charge may be decomposed in a single fusion with the same certainty as a small charge. My preference is for sodium peroxide over caustic soda; a preliminary fusion is unnecessary and it has a slightly higher melting-point.

Of the methods based on selective attack, I have yet to meet the true mineral which is not amenable to the Beringer method. The limitations of the hydrogen (or coal gas) attack are well known and the method has been adopted to meet such limitations; so, too, there are a few instances where the lime method has limitations

which may also be met. By analogy I should expect reduction with carbon to have similar limitations.

My views on nickel have been recorded during the discussion, except for some aspects which call for further remarks. It is quite true that zinc as a method of separating tin is not new, nor for that matter is its use as a partial reducing agent in the tin assay. In the Beringer assay it is an integral feature of the method, and in its application it is for all practical purposes 'zinc-nickel' reduction: only in special circumstances is an attack with chlorine followed by nickel reduction practised. In the development of the method by Beringer in the earlier stages he used the chlorine attack with nickel reduction; in later stages the shorter method or zinc-nickel reduction.

In the introductory paper on the lime method, the author gave details of zinc-nickel reduction as applied to that method, also in the reply a method in which nickel reduction only figured. The only new feature in the present communication was the application of zinc-nickel reduction to the Pearce assay. It has fallen to my lot to make an acquaintance with all three methods of attack combined with the dual conditions for the reduction of the tin solution. It is not easy to express the experience gained under such conditions in a paper of this kind, but the experience has been such as to establish zinc-nickel reduction as preferable to nickel reduction. My preference has been construed as an attack upon nickel, and the experiments with various brands of nickel in the presence of titanium have been quoted as true of nickel in general.

I know of no brand of nickel which in a blank test with hydrochloric acid would have to be rejected because of consumption of iodine: any of the brands of nickel mentioned would give concordant results with a stock solution of tin. A solution of tin ore or concentrate in hydrochloric acid reduced with nickel, not infrequently consumes iodine slowly with an indefinite end point, a fact which suggests the necessity of acid cleaning rather than a rejection of the nickel.

The work of Beringer with a solution of titanium trichloride showed that the presence of $TiCl_3$ was not the only factor concerned in the interference. $TiCl_3$ as a pseudo triad is best pictured as a balanced product between $TiCl_2$ and $TiCl_4$: a prolonged digestion with a metal like nickel would tend to disturb the balance in the direction of more $TiCl_2$ (within limits) with a tendency to a restoration of the balance during titration. One metal would differ from another in its effect, and an impure nickel by reason of local couples from a purer nickel, and a prolonged reduction with any given

metal more harmful than a shorter reduction, as experience has shown, is true with the ordinary nickel reduction.

With zinc-nickel reduction under the conditions defined in the paper the effect of titanium appears to be practically eliminated; on the evidence of the titrations to which Mr. Picard has referred, the brand of nickel ceases to be of any importance. It is, if confirmed by the experience of professional assayers, a strong point in favour of zinc-nickel reduction. Confirmation is easy on the lines suggested with aliquot parts, one of which is reduced with zinc-nickel, and the others separated on zinc from the titanium; a few examples will suffice.

The advocates of iron are silent as to the effect of titanium under such conditions. On other points their attitude is a curious one, for whilst nickel is disparaged because of impurities and other imperfections which I do not entirely agree, iron is recommended with cautions against various kinds of iron. Mr. Griffith has put his convictions into data, but I suggest that he or any other advocate of iron would do good to all by giving a more or less detailed comparative study of the reduction of tin solutions by both nickel and iron.

A long experience in the preparation of samples personally does not allow me to sympathize with the 'dusting' theory.

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Subject to revision.] [*A Paper to be discussed by correspondence. Written Contributions should be in the hands of the Secretary before September 30th, 1917.*]

Leaching of Copper Ores at Bisbee, Arizona.

By JOSEPH IRVING, *Associate.*

THROUGH the courtesy of the Copper Queen Consolidated Mining Co., I am at liberty to give the following results on the leaching of certain copper ores, which may be of some interest at this time when so much experimental, as well as commercial leaching is being carried on, partly in the line of direct leaching, and partly roasting with subsequent leaching.

The work described is an adoption of what is sometimes called the 'brutal method,' i.e. leaching with sulphuric acid and recovering the copper by precipitation on iron, with the exception that in this instance the iron is not all lost, and the process is cyclic in operation. Further, it is always possible to combine an electrolytic recovery with iron precipitation, regenerate some sulphuric acid, make use of the waste liquor from the precipitation tanks, thereby maintaining the cycle of operation, and work in the copper precipitate with the electrolytic recovery, so that the final product is electrolytic copper.*

The information gained may be generally interesting in view of the fact that it appears possible to treat successfully by direct leaching, and a moderate use of sulphuric acid, a class of ore which hitherto has demanded a heavy expense in acid, or a preliminary roast, so as to obviate these elements which contribute to a high consumption of acid. The ore particularly selected for the leaching tests was a highly aluminous oxide ore of which the following is a representative analysis:

Cu %	Fe %	CaO %	Al_2O_3 %	S_1O_2	Z_2
3·20	29·50	2·65	12·50	24·23	2·25

Attempts to treat this ore by the usual milling methods now in vogue were not very successful, and the analysis shows that it decidedly is a refractory smelting ore.

Some apprehension existed as to the probability of high alumina and iron and also lime, entering the leached liquor with the copper, thereby inferring not only an unusual consumption of acid in the leaching process but the presence of iron and alumina in the lixivium

*Patent applied for.

in such excess as probably to interfere with electrolytic recovery. Previous work in Nevada having determined that the presence of lime even up to 20% can be overcome, and its acid-consuming power destroyed, if the ore be first treated with a solution containing ferrous and ferric sulphates, it was decided to work along similar lines, in the hope that something of the same effect would result when iron oxides and alumina were present in quantity, and likely to be dissolved out if preliminary treatment were made with strong acid solution.

As is usual in such work a number of laboratory tests were first tried to find out if the ore were at all amenable to a leaching treatment. The results of these laboratory tests were quite satisfactory, showing a good extraction with a consumption of two parts of sulphuric acid to one part of copper. Two results are given herewith:

Heads	2·20	3·82
Tails	0·30	0·30
Extraction	1·90 = 86·3 %	3·52 = 92 %

NOTE.—Ore crushed to 8 mesh; 100 grm. taken, treated with waste liquor from cementation plant, (containing ferrous and ferric iron) fortified with sulphuric acid: normal temperature and intermittent agitation. Further tests on small quantities gave somewhat similar results.

These tests were supplemented by heavier tests treating from 50 lb. to 100 lb. at a time in small vats which permitted of intermittent steam and air agitation. The average temperature was 110° F., and the average extraction from nine tests out of thirteen was 83%. It was noticed at this time that by judicious application of lixiviant weak in acid, but strong in ferrous and ferric salts the solution of copper was easily effected, while at the same time the proportion of iron, lime and alumina dissolved out was almost negligible, even when the first lixiviant, weak in acid, was followed by a solution strong in acid.

FILTRATES FROM THREE LEACHING VATS,
SHOWING PROPORTION OF METALS DISSOLVED OUT,
AND REPORTED IN GRAINS PER GALLON.

Copper.	Ferrous Iron.	Ferric Iron.	Lime.	Alumina.
2951	620	355	95	267
2166	173	280	104	236
3579	1,100	77	49	260

This may be illustrated in another way:

	Copper %.	Iron %.	Alumina %.
Ore	3·82	29·00	11·60
1st Leach	1·50	0·20	0·04
2nd „ (wash)	0·30	0·16	0·04
3rd „ „	0·12	0·16	0·03

Another lot checked by tails gave the following results:

	Copper %.	Iron %.	Lime %.	Alumina %.
Heads	3·20	29·0	2·5	12·50
Tails	0·55	28·0	2·0	15·00

The slight increase in alumina in the tails is partly due to some f the washings being made with rather foul waste liquor which ad become charged with alumina, particularly towards the end of he run.

These figures show that the amount of iron, lime, and alumina issolved out is very small indeed, compared with the copper, and roves that little of the solvent is lost in dissolving those etrimentals.

It was finally decided to follow up these small scale tests by reating some of the ore in approximately one-ton lots. A small xperimental leaching plant, capable of handling three tons at a ime, one ton in each leaching tank, was accordingly set up. No rushing plant was installed, as it was arranged to have the iecessary crushing done at the sample mill.

The accompanying flow sheet shows a small tube mill, which ras not put in, as it was considered that good results might be btained without it. The explanatory legend of the flow sheet, ierewith, gives general details of procedure. The drawings here-rith show a device for emptying the tanks, and transferring pulp rom one to another and finally to waste. A lever was attached to he plug and worked from a point beyond the tank; the plug was owered only a few inches and the pulp discharged into a launder. 'he pulp as fed into the tank, fell on the cone, and so the charge ras evenly distributed all over the tank. These leaching tanks were rovided with false bottoms of 1 in. boards, perforated with ½ in. ioles, and covered with one layer of cocoa matting.

In the pyritic filter tanks the percolation was upward (*see* 'ig. 4), the precipitating tanks were also provided with false ottoms of 6 in. × 4 in., on which the iron was laid. The opper liquor entered these tanks by a downtake in the centre, oming up through the iron, and flowing off near the top, thus nsuring thorough contact with the iron. The false bottom arrange-nent permitted collection of the copper precipitate without removing

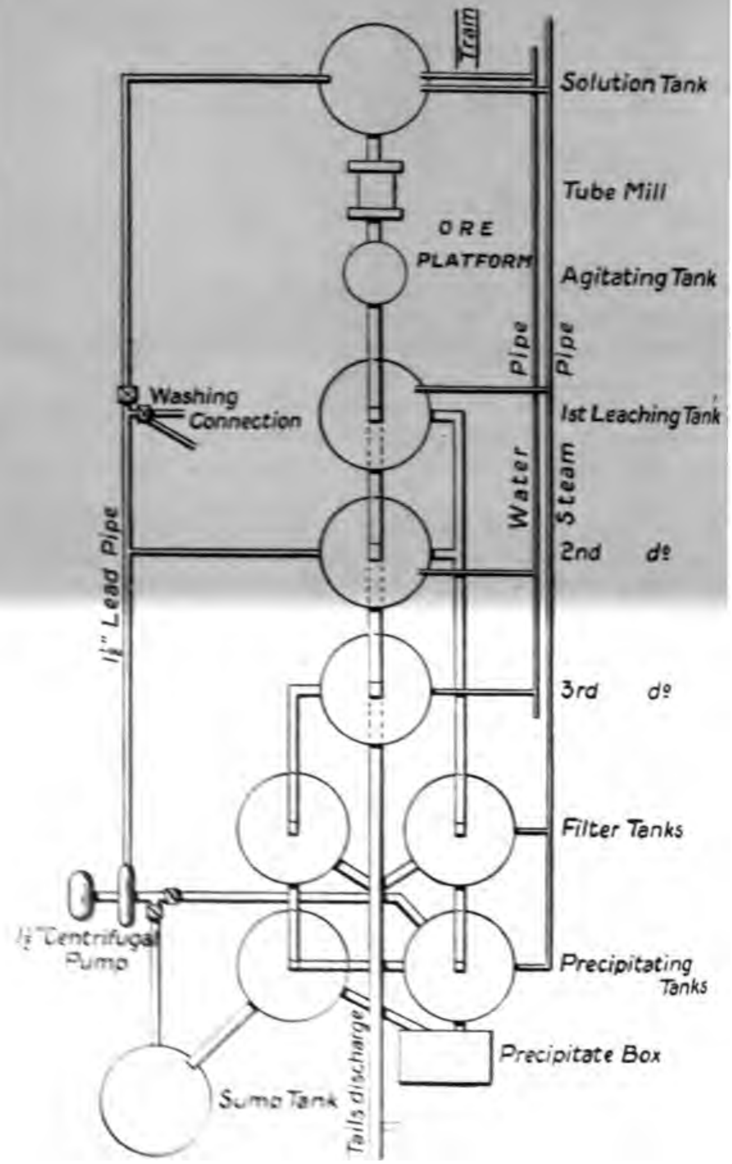

FIG. 1.—Arrangement of the Experimental Copper Leaching Plant, Copper Queen Consolidated Mining Co., Bisbee, Arizona.

EXPERIMENTAL LEACHING PLANT.

FLOW SHEET.

FLOW OF LIQUORS AND ORE.

1. Ore is fed to agitating tank along with solution from solution tank.
2. Discharge from agitating tank goes to No. 1 leaching tank.
3. Liquor is drained from No. 1 leaching tank to No. 1 filter tank. Ore is discharged by means of liquor from sump tank into No. 2 leaching tank.
4. Liquor is drained from No. 2 leaching tank to No. 1 filter, mixing with the solution from No. 1 leaching tank. Ore is discharged into No. 3 leaching tank by means of liquor from sump tank.
5. Liquor is drained from No. 3 leaching tank to No. 2 filter. Ore is washed out of No. 3 leaching tank to waste by means of water.
6. Liquors from No. 1 and No. 2 leaching tanks are filtered in No. 1 filter tank, from whence they overflow to No. 1 precipitating tank.
7. Liquor from No. 3 leaching tank goes to No. 2 filter tank, where it is filtered, overflowing to No. 2 precipitating tank.
8. The liquor from No. 1 precipitating tank overflows to No. 2 precipitating tank.
9. The liquor from No. 2 filter tank overflows into No. 2 precipitating where it mixes with partly precipitated solution from No. 1 precipitating tank. The overflowing solution from No. 2 precipitating goes into sump tank from whence it is pumped by means of solution pump to discharge the sands from No. 1 and No. 2 leaching tanks, and to supply solution tank No. 1.

one tank to another with a ferrous solution of the usual consistency, pumped direct from the sump tank to the leaching tank.

The following day more of the copper solution was drawn off, and a second wash given to the pulp, when the charge was transferred from the second to the third leaching tank, and allowed to lie overnight. Further decantation or filtration would be followed by another (water) wash which generally completed the treatment. It will be seen from the foregoing that the plant admitted of three charges, in different stages, under treatment at one time.

The waste liquor used for charging and washing purposes showed a steady increase in iron during the period of operations, rising from 0·10 % in the first few days to 1·30 % at the end of the campaign, which goes to prove that the ferrous salts are always in abundance.

It is also comparatively easy to control this accumulation. The change from ferrous to ferric iron takes place, partly when pumped up and aerated in the solution tank, and partly in the first stages of the leach; (*see* accompanying table of results).

Charging with the necessary acid added to the ferrous solution was tried on several occasions, and resulted in a saving of time, but the extraction was not quite so good. In further regard to the time problem, many trials were made, and it was found that an over-night leach, on ore ground to 8 mesh, properly started and steamed to about 110° F., got out most of the copper, and in fact a 48 hours' leach, or even a 72 hours' leach, did not seem to get out more copper, unless in one or two cases where the charge was very coarse, when extra time certainly proved advantageous.

For example:

RESULTS IN GRAINS PER GALLON.

24 hours' leach.	48 hours' leach.	72 hours' leach.
1094·80	1073·00	—
1096·20	—	1032·40
907·70	874·40	—
969·80	—	962·20
1764·70	1658·80	—
1496·40	—	1560·2

This last lot contained 29·50 % coarser than 8 mesh.

Comparing the results from the small scale tests, with the results from the larger tests, it is evident that the want of agitation detracted from the latter. The agitator used in charging was really more of a distributor, and simply helped to mix the charge with the solution on its way to the leaching tank. To emphasize the value of agitation, a séries of 100-lb. tests were carried on, duplicating some of the heavy charges in every particular with the added benefit of agitation.

Pounds.	Heads.	Tails.	Ext.	Precipitate produced.		Actual Recovery.
				lb.	Cu. %	
100	3·30	0·70	79·0	3·60	76·50	83·6
100	3·10	0·60	80·5	3·30	74·38	80·0
100	3·10	0·88	71·0	3·25	84·78	88·8

Some results are given on a separate sheet, which to a great extent explain themselves. The results from the first two filtrates only are given, as these tend to show all the action; each charge got at least four washings, but after the first it was simply a case of washing the pulp free of dissolved copper. Washings in the leaching tanks were by upward percolation. These washings took considerable time, running into three and four days, and it seemed as if in that time some of the copper was caught and held up by the slimes. A quick counter current washing system, or combined agitation and replacing system is the proper remedy for that.

As these results were obtained on ore crushed to approximately 8 mesh, it will be readily appreciated that the same class of ore crushed to 20 mesh, and subjected to agitation, would give better returns in soluble copper; and as for the extra slimes they, as already suggested, could be taken care of by quick washing.

In sixteen charges, totalling 769 lb. copper, the results as calculated from heads and tails assays showed an extraction of 77·10%, while the actual copper precipitate produced from these charges was 964 dry lb., @ 62% copper, indicated a recovery of 78·60%.

The amount of sulphuric acid consumed per lb. of copper, while not prohibitive, might be considered high. This, however, would be modified to a great extent by adopting a combined electrolytic recovery with iron precipitation, the electrolytic method regenerating sulphuric acid to the extent of 1·5 lb. H_2SO_4 per lb. of copper deposited.

As it has been frequently suggested that gold and silver* cannot be recovered by leaching unless the ore has had a preliminary roast, it might be interesting to note here that by adopting the foregoing direct method of leaching, with the addition of salt and working on a raw material, gold and silver have been recovered, with the copper at one and the same time, when these metals were present in appreciable quantities, extraction varying in different ores and compounds from

56 %—92 % of the copper.
60 %—83 % of the silver.
41 %—75 % of the gold.

Precipitates produced have run as high as

68·52 % copper.
189 oz. silver per ton.
1 oz. gold per ton.

These results were obtained in one direct treatment, the gold and silver being precipitated with the copper.

To come back to even more primitive methods, however, there is a possibility of heap leaching attaining as much success in the South Western States, as it does in Spain and South Australia. It was long contended that heap leaching could be successfully applied only to heavy sulphide ores. However, more recent practice has shown that heap leaching of ores in which the copper may be combined with small quantities of iron pyrites in a heavy siliceous gangue can be so treated in piles even up to 20 ft. high, as for example at Aznalcollar, near Seville, Spain, one essential being that facilities are established for washing with waste ferrous and ferric liquors as these elements help materially in the washing and the leaching of such heaps. With this end in view numerous tests have been carried out on low-grade ores from New Mexico and Arizona, having an average consistency of:

	Copper %	Silica %.	Iron %.	Lime %.	Alumina %.	Sulphuric Acid %.
Bisbee, Ariz. ...	1·30	60·70	10·50	1·20	12·80	9·90
Tyrone, N.M. ...	2·44	69·37	5·0	—	14·62	3·44

Tests on 200-lb. lots and up to 10-ton lots have proved that by treating this low grade material with waste liquors from a cementation plant it is possible to extract, by percolation alone, from 30 % to

* U.S. Patent 1048541, December 31, 1912.

60 % of the copper content in three months. In fact, on particularly favourable ore, i.e. which has been weathered for some time, an extraction of 50 % was obtained in thirty days. A more complete extraction is simply a question of due care and time, and even on the most refractory ore which we have tried, a conservative estimate might be two years for an 80 % recovery. Without going into details of tramming, heap-building, plant, etc., a general treatment charge covering everything even to the cost of iron for precipitation will be about $1·00 per ton of ore, so that on low grade material containing 25 lb. copper to the ton and on a 75 % recovery with copper at even 15 c. per lb. there is plenty of margin to make the work remunerative.

Heaps have been laid out at Tyrone, New Mexico, and at Bisbee, Arizona, on the same general line as at Rio Tinto, Tharsis and Aznalcollar on prepared floors, with culverts and drains of rock and ore, leading to a central settling tank. Precipitation will be partly in tanks and partly in canals, which will be all wood.

⁂ *Extra Copies of this paper may be obtained, at a nominal charge, at the Offices of the Institution, 1, Finsbury Circus, London, E.C. 2.*

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…ving : *Leaching of* …

	Heads.
	Ore, lb.
	Copper °/…
	Iron °/o
	Silica °/o
	Alumina …
	Lime °/o
	Zinc °/o
… Liq.	lb. ....
…ging	Copper °/…
…d	Iron °/o″
…ing.	Iron °/o‴
	Alumina …
	Acid °/o
…ltrate.	lb. ....
	Copper °/…
	Iron °/o″
	Iron °/o‴
	Alumina …
	Lime °/o
	Acid °/o
…trate.	lb. ....
	Copper °/…
	Iron °/o″
	Iron °/o‴
	Alumina …
	Acid °/o
	Copper °/…
	Iron °/o
	Silica °/o
	Alumina …
	Zinc °/o
…d per lb.	Copper …
…e Tem.	°F. ....
…ng time	Hours ..
…g time	Hours ..
…ion	°/o by Ta…
	°/o + 8 m…
	°/o +20 m…
	°/o +48 m…

	Heads.
	Ore, lb.
	Copper %
	Iron %
	Silica %
	Alumina
	Lime %
	Zinc %
e Liq.	lb. ....
·ging	Copper %
ıd	Iron %"
ıing.	Iron %'''
	Alumina
	Acid %
ltrate.	lb. ....
	Copper %
	Iron %"
	Iron %'''
	Alumina
	Lime %
	Acid %
ltrate.	lb. ....
	Copper %
	Iron %"
	Iron %'''
	Alumina
	Acid %
	Copper %
	Iron %
	Silica %
	Alumina
	Zinc %
.d per lb.	Copper
e Tem.	°F. ....
ng time	Hours ..
ng time	Hours ..
tion	% by Ta
	% + 8 m
	% +20 m
	% +48 m

Experimental Leaching Plant,
Copper Queen Consolidated Mining Co., Bisbee, Arizona.

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Subject to revision.] [*A Paper to be discussed by correspondence. Written Contributions should be in the hands of the Secretary not later than September 30th, 1917.*]

Note on the Purity of Selected Copper made in Converters.

By HENRY F. COLLINS, *Member.*

REFERENCE has been made in a former paper* to the bottom process carried out in converters as practised by the author in Spain, for which, however, he can claim no priority, since although evolved independently, the same method has been previously employed by other metallurgists in Australia. Soon after the outbreak of war in 1914, the Huelva Copper Co. was led to employ this method in order to save part of the gold contents and to facilitate the utilization of their product in Spain for the making of brass for munitions, as well as bronze for coinage and other alloys, without further previous refining. It is noteworthy that practically the whole of the output produced by this method has been saleable upon the basis of Best Selected or at most with a deduction of 1*l.* or 2*l.* from the full Best Selected quotation, and as regards freedom from impurities the copper is considered as quite of Best Selected quality for the making of alloys, particular testimony to this fact having been afforded by its utilization for coinage purposes at the Madrid Mint. For rolling, the copper is of course unsuitable, on account of gas pores and because the slight excess of oxygen renders it brittle, so that for this purpose it must be remelted and 'brought to pitch.'

In order that the copper as cast from the converters may be pure enough for brass making, it must be very slightly overblown. The operation is, however, one of some delicacy, and great care must be taken not to overshoot the exact point, since too much oxygen would be injurious to the quality of the resulting brass. The reaction between residual combined sulphur and dissolved oxygen is still proceeding when the operation is finished, but on account of chilling, the charge cannot be left in the converter long enough to admit of settling down to tranquil fusion. When employing small converters holding charges of from 15 to 30 cwt. of copper, no difficulty was, however, experienced in pouring direct from the converter, without serious chilling, into small-sized ingot moulds holding about 44 lb. apiece instead of the much larger pigs of

**Trans. I.M.M.*, vol. xxiv, 1915, p. 489.

140 to 220 lb. into which converter copper is ordinarily cast. The ingots are dumped into water tanks in the ordinary way for Best Selected copper, and show the same characteristic rose-red colour. Their upper surface is, however, marred by blisters arising from the expulsion of SO_2 upon solidifying, and as already stated, the excess oxygen which it is necessary to introduce in order that the impurities may be sufficiently expelled makes the ingots too brittle for rolling.

In order to show the exceptional freedom from deleterious impurity of the copper produced from very arsenical zincy and leady ores by the selecting process, two analyses are appended, each of which is the average sample of a lot of from 20 to 50 tons and represents the average of a large number of charges mixed together. Two analyses are also given of the 'bottom,' in order to illustrate the extent to which the impurities are separated out.

	Selected Copper.		Bottom Copper.	
Copper	99·4400	99·4100	96·7800	97·9700
Silver	·0860	·1060	·1522	·1724
Gold	·0015	·0010	·0146	·0206
Nickel	·1322	·0966	·1680	·2410
Cobalt	·0440	·0256		
Iron	·0150	·0353	·5500	·5600
Arsenic	·0029	·0031	·0058	·0058
Antimony	·0016	·0012	·0045	·0030
Bismuth	·0017	·0007	·0016	·0030
Sulphur	·0860	·0364	1·4600	·7770
Lead	·0888	·0253	·1170	·0370
Zinc	·0096	·0240	·0890	·0290
Insoluble (slag)	tr.	tr.	·5600	·0510
Oxygen and Loss	·0907	·2348	·0973	·1302
	100·0000	100·0000	100·0000	100·0000

If it be desired to sell copper which shall be suitable for rolling, drawing and all other commercial purposes, as well as for the making of alloys, it is necessary to pour the contents of the converters into a reverberatory refining furnace, in which, after allowing the reactions which are still proceeding at the moment when the charge is finished to be completed, the charge is 'poled' as usual to reduce excess dissolved oxide and bring it to pitch. At the works of the Huelva Co., this additional operation of reverberatory

ıing is not undertaken, because the small output of the works the very high price of fuel would not justify the extra expense. erberatory refining of converter-selected copper is, however, ied out at a well-known Australian works, when copper is ıg handled which is too low in gold and silver contents to ify electrolytic refining of the whole of the copper.

he bulk of the precious metals present (particularly gold) being concentrated into 'bottoms' for electrolytic refining, the ected' copper produced by the remainder of the converter charge poled' and brought to pitch in a reverberatory refining furnace, n which it is cast into ingots of the usual Best Selected type. se are known as 'fire-refined' copper, and have been recently gnized by the London Metal Exchange under that title as of ıl quality to Best Selected. In order to show its purity, the owing analyses may be quoted, each of which represents the age sample of a large lot as shipped.

	Fire-refined Copper.		
per } er }	99·5800	99·6000	99·6200
d.......................	—	—	—
kel and Cobalt	·3390	·3300	·2800
ı........................	·0045	·0040	·0030
ɜnic	·0038	·0040	·0030
imony	tr.	tr.	tr.
nuth	tr.	tr.	tr.
phur	—	tr.	tr.
nium and Tellurium	tr.	tr.	tr.
d	·0006	·0050	·0050
ɜ.......................	—	—	—
....	tr.	—	—
luble..................	—	—	—
gen by difference ...	·0721	·0570	·0890
	100·0000	100·0000	100·0000

ity in copper, silver and nickel combined:

	99·92	99·93	99·90

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Lockhart, Thomas Lamb (*Johannesburg, Transvaal*).
Wilson, Archibald Laurence (*Ravenswood, North Queensland*).

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Ellis, Leonard Victor (*Dunedin, New Zealand*).
Gordon, Hugh Thomas (*Dunedin, New Zealand*).
Landreth, Robert Faulks (*Dunedin, New Zealand*).
Scoular, Russell Calvert (*Dunedin, New Zealand*).

The following have applied for Transfer:—

To Associateship—

Dorrington, Harold Roy (*Wistow, Huntingdon*).
Striegler, Louis Johann (*Marikuppam, S. India*).

MOVEMENTS OF MEMBERS.

Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. A. E. Bidlake, Assoc. Inst. M.M., has returned to England from West Africa, on leave.

Mr. W. Lyman Brown, M. Inst. M.M., is remaining in Rotterdam as Director in charge of the operations of the Commission for Relief in Belgium.

Mr. M. A. Bruce, Assoc. Inst. M.M., has returned to England from Northern Nigeria, on leave.

Mr. Zachariasw Daw, M. Inst. M.M., is returning to England from Burma.

Mr. J. Reed, Assoc. Inst. M.M., is still in the Republic of Colombia, and not in England as was stated in the June *Bulletin.*

Mr. Archibald Stark, M. Inst. M.M., has left England for Mexico.

Mr. H. W. Turner, M. Inst. M.M., has been appointed General Manager of the Oroville Dredging, Ltd. (the American Company).

Mr. A. Stanley Williams, M. Inst. M.M., has left England for Northern Nigeria.

Mr. William R. Wright, Assoc. Inst. M.M., has left England for Mexico.

ADDRESSES LOST.

F. B. Bradshaw, O. L. de Lissa, and D. Nicholas.

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MINING (General).

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Three big American Gold Dredges.— The Mining Magazine, London, Vol. 16, June, 1917, pp. 295-9. 1s.

Utilization of Peat for the production of Sulphate of Ammonia and of Power. L. Simpson.—Canadian Mining Journal, Toronto, Vol. 38, April 1, 1917, pp. 150-1; May 1, 1917, pp. 191-2. 15c.

MILITARY SERVICE.

SUPPLEMENTARY LIST.

The following have been notified since the issue of the last Bulletin, June 28th, 1917:

MEMBERS SERVING WITH H.M. FORCES.

Albu, C. A., Royal Engineers, (2nd Lieut.).

Burgess, Chas. A., Chinese Labour Corps, (2nd Lieut.).

Cairns, J. M., General List, (Lieut.).

Glen, Alexander, Royal Engineers, (2nd Lieut.).

Jones, J. Evans, Royal Engineers, (Lieut.).

McLeod, B. H. H., Royal Flying Corps, (2nd Lieut.).

Mitchell-Withers, W. C., Honourable Artillery Co., (Sergeant).

Phillips, S. F., Cape Corps, (Lieut.).

Weekes, A. B. (*No particulars*).

PROMOTIONS OR OTHER CHANGES.

Dare, N. F., M.C., Royal Field Artillery, (Captain). *Awarded Bar to Military Cross.*

Gilbert, T. W., Royal Garrison Artillery, (Lieut.).

Greatwood, H., Royal Field Artillery, (Lieut.).

Hannay, H., King's Own Scottish Borderers, (Captain), (attached to Royal Engineers). *Awarded the Military Cross.*

Haworth, A., Army Service Corps, (M.T.).

Kellett, A. G. Reid, South Wales Borderers, (Pioneers), (Major).

Nissen, P. N., D.S.O., Royal Engineers, (Lieut.-Col.).

Pitt, C. H., Royal Engineers, (Captain). *Awarded the Military Cross.*

Syme, G. A., M.C., Royal Engineers, (Major). *Awarded the D.S.O.*

Tulloch, Ewan, M.C., Royal Engineers, (Major). *Awarded the D S.O.*

KILLED IN ACTION.

Henry Noel Grist, *Associate*, 2nd Lieut., Royal Engineers. (On May 27th, 1917.)

Crowther & Goodman, Ltd., Printers, 124, Fenchurch Street, London, E.C. 3.

...e Institution of Mining and Metallurgy.

(*Founded 1892—Incorporated by Royal Charter 1915.*)

Bulletin No. 155.

August 23rd, 1917.

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OF

The Institution of Mining and Metallurgy, 1917-1918.

CANDIDATES FOR ADMISSION.

The Council welcome communications to assist them in deciding whether the qualifications of Candidates for Admission into the Institution fulfil the requirements of the By-Laws.

The Application Forms of Candidates for Membership or Associateship will be open for inspection at the Office of the Institution for a period of at least two months from the date of the Bulletin in which their applications are announced.

The following have applied for admission since July 26th, 1917:—

To Studentship—

Hawkey, Wilfred Alwyn (*Laureath, Cornwall*).
Rout, Dina Bandhu (*Chota Nagpur, India*).

The following have applied for Transfer:—

To Membership—

Dick-Cleland, Archibald Felie (*B.E.F.*).
Entwistle, Albert Lucas (*Ottawa, Canada*).
Venables, Harry Leonard (*Oruro, Bolivia*).

To Associateship—

Ridge, Cecil Harold (*London*).

NEW MEMBERS.

The following have been elected (subject to compliance with the conditions of the By-Laws) since July 26th, 1917:—

To Membership—

Caddick, Arthur James (*Rio Tinto, Spain*).
Scott, Frederick Bowes (*Salmon Arm, British Columbia*).

To Associateship—

Cramer, Dwight Lewis (*Tavoy, Lower Burma*).
Daddow, Samuel (*Shamva, Southern Rhodesia*).
Graham, Harry Woodthorpe (*B.E.F.*).
Hill, John Whitelaw (*Naraguta, Northern Nigeria*).
Lawn, Herbert (*Dalton-in-Furness, Lancashire*).
Rance, Bernard (*Mogok, Upper Burma*).
Soar, Vincent Douglas (*B.E.F.*).
Ward, Arthur Thomas (*Rancagua, Chile*).

NEW MEMBERS—*continued.*

To Studentship—

Dempster, Ian Mackay (*St. Ives, Cornwall*).
Ellis, Leonard Victor (*Dunedin, New Zealand*).
Gordon, Hugh Thomas (*Dunedin, New Zealand*).
Griffith, Stanley Vincent (*Camborne, Cornwall*).
Landreth, Robert Faulks (*Dunedin, New Zealand*).
Ranger, John Osborn (*B.E.F.*).
Scoular, Russell Calvert (*Dunedin, New Zealand*).
Waddell, James Robert (*London*).
Yipp, George Wing (*Camborne, Cornwall*).

The following have been transferred:—

To Associateship—

Blandford, Stanley Charles Hooper (*Coronel, Chile*).
Jones, Edward Oswald (*B.E.F.*).
Plummer, Benjamin Douglas (*B.E.F.*).
Richards, James Foster (*B.E.F.*).
Sellers, William George (*London*).

MOVEMENTS OF MEMBERS.

Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. P. St. John Dixon, Assoc. Inst. M.M., has been appointed Chief Surveyor of the Dome Mines, Porcupine, Ont., Canada.

Mr. Charles C. Scott, M. Inst. M.M., has returned to England from the Straits Settlements.

Mr. R. O. H. Spence, Assoc. Inst. M.M., has left England on his return to British Guiana.

Mr. Walter J. Stanford, M. Inst. M.M., is returning to England from Siberia.

Mr. D. A. Thompson, Assoc. Inst. M.M., has left England on his return to West Africa.

Mr. S. S. Webb-Bowen, Assoc. Inst. M.M., has returned to England from Northern Nigeria, on leave.

ADDRESSES LOST.

F. B. Bradshaw and D. Nicholas.

INDEX OF RECENT BOOKS.

)TE.—Books marked with an asterisk are contained in the Library of the Institution.

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GOLD.

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Members of the Institution are invited to send information in regard to their movements to the Secretary for insertion under this heading. Members visiting London are requested to register their addresses at the House of the Institution, where the Library, Writing Rooms, etc., are at their disposal.

Mr. C. G. Larsen, Stud. Inst. M.M., has left Norway for Newfoundland.

Mr. A. Rosewarne, Assoc. Inst. M.M., has returned to England from a trip to Peru.

Mr. Thomas P. Sharman, M. Inst. M.M., has left Ontario on a visit to Western Canada.

Mr. R. A. Wade, Assoc. Inst. M.M., is with the Aeronautical Inspection Department at Filton, Bristol.

Mr. A. B. Watson, Assoc. Inst. M.M., has left England for Northern Nigeria.

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MILITARY SERVICE.

SUPPLEMENTARY LISTS.

The following have been notified since the issue of the last Bulletin, August 23rd, 1917:

MEMBERS SERVING WITH H.M. FORCES.

TAVERNER, L., Royal Naval Volunteer Reserve, (Sub.-Lieut.).

PROMOTIONS OR OTHER CHANGES.

PARTRIDGE, S. C., Royal Engineers, (2nd Lieut.).

QUAYLE-DICKSON, E. J., Royal Engineers, (Captain). *Awarded the Military Cross.*

WOAKES, RUSSELL B., Q.V.O. Sappers and Miners, (Lieut. Indian Army Reserve of Officers). *Awarded the Military Cross.*

KILLED IN AOTION.

CHARLES RUSSELL CHAFFEY, *Student*, 2nd Lieut., Manchester Regiment. (*In March, 1917.*)

GERARD OWEN LYDEKKER, *Student*, Lieut., Bedfordshire Regiment. (*Died at Alexandria on June 14th, 1917, of tropical disease.*)

FRANK REMINGTON PRETYMAN, *Student*, 2nd Lieut., Royal Engineers. (*On July 4th, 1917.*)

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CONTRIBUTED REMARKS TO THE DISCUSSION

ON

'Hydraulic Tin Mining in Swaziland.'

By J. J. GARRARD, *Member.*

Mr. T. R. A. Windeatt: The efficiency figures given by Mr. Garrard are extremely interesting, particularly as they are not the results of isolated tests, but are the averages taken over a period of twelve months.

In Table I, I have tabulated the details of a test which I made over the month of September, 1912, of an open throat hydraulic elevator then in use on Tekka, Ltd., in the Federated Malay States. To facilitate comparison between this test and that conducted by Mr. Garrard I have included his figures in the table.

The results are remarkably similar to those obtained by Mr. Garrard, but the low lift elevator has the higher efficiency.

Since 1912, many attempts have been made to improve on the type of elevator then in use, but, although the cost of the wearing parts has been much reduced, only a slight improvement in efficiency has been obtained.

The type of elevator used in the test (Table I) is almost identical in outline to the elevator shown in the diagram on p. 17 of the paper.

Gravel Pumps.—The allowance made in the formula for obtaining the gravel pump efficiency requires further explanation. In a note (p. 19) Mr. Garrard states that :—'85 % is allowed for electrical transformation and transmission losses from the head box of power plant to current put into motors at pumps.'

If by the power at 'head box' the power in the water at the Pelton wheel is meant, then the allowance of 85% does not appear to be sufficient.

In a plant of this description the losses would probably be not less than :—

Pelton wheel	20·0 %
Generator	8·0 ,,
Step up transformers	2·5 ,,
Step down transformers	2·5 ,,
Transmission line	12·0 ,,
Motor	10·0 ,,
Total losses	55·0 %

Taking the above figures as being correct, the allowance in the

formula for losses will then be 45 %, making the overall efficiency of the gravel pumping plant 23·76 % instead of 28·1 %.

If the efficiency (E) in the formula represents the mechanical efficiency of the motor and pump, it is unnecessary to introduce any factor for electrical losses, as the actual number of units consumed was recorded by a wattmeter on the barge. The mechanical efficiency of the motor and pump from the figures given is 43·23 %.

On the other hand, if 35 % is the electrical loss, then 28·1 % does not give the overall efficiency, because the Pelton wheel losses have not been considered; this figure, therefore, cannot be fairly compared with the elevator efficiency of 16·58 %.

The following details of the gravel pumping plant at Heawood Tin Mine (Federated Malay States) may be of interest.

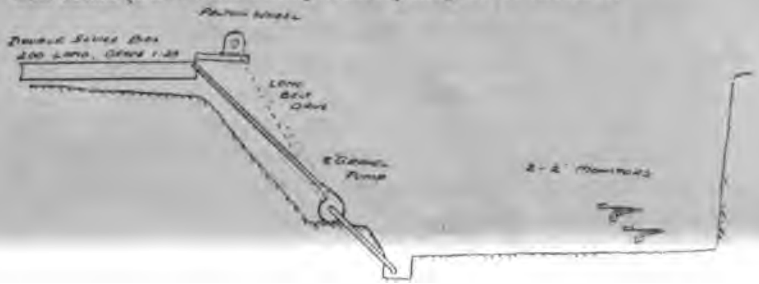

Diagram showing arrangement of installation (May, 1917).—Pipes supplying monitors and wheel are not shown.

The plant consists of two monitors and an 8-in. gravel pump which is driven with a long belt by a Pelton wheel.

The material is elevated into a two-compartment sluice box. The Pelton wheel is above the sluice box, and the discharge water is used for 'cleaning up' (the boxes are streamed down on separate days), and also to assist in the sluicing when the two compartments are running at the same time.

Pelton Wheel.—Size of wheel 24 in.; nozzle, controlled by needle valve, maximum size $1\frac{1}{8}$ in.

Effective head.—The gauge pressure was 220 lb. per sq. in., the nozzle being 6 ft. 6 in. above the gauge.

Effective head = 508 − 6 ft. 6 in. = 501·5 or say 500 ft.

Quantity of water used.—Measurements were taken at a rectangular weir, 20 in. wide, at the discharge of the wheel. Depth of water flowing over weir = $5\frac{1}{4}$ in.

Quantity of water (from tables) = 4·67 × 20 = 93·40 cub. ft. per min.

$$\text{Theoretical hp.} = \frac{\text{weight of water (lb.)} \times \text{effective head (ft.)}}{33000}$$

$$= \frac{93{\cdot}40 \times 62{\cdot}5 \times 500}{33000} = 88{\cdot}44$$

The gravel pump lifts the water and solids from two 2-in. monitors at 65 lb. pressure and also 20 cub. ft. per min. (estd.) of seepage water.

Monitors.—Nozzles	2—2 in.			
Pressures	each 65 lb. per sq. in.			
Effective Head	150 ft.			
Discharge	2 × 120·9 = 241·8 cub. ft. per min.			
Seepage		20	do.	do.
Total water raised		261·8	do.	do.
Yardage cut (by monthly survey)		18000·0 cub. yd.		

The ground treated is a soft clay soil containing about 50 % sand. 9·67 cub. ft. of water per min. are required to break down 1 cub. yd. of ground per hour.

Gravel Pump.—Size .... 8 in.

Speed .... 482 rev. per min.

H = Height lifted in feet	45·7 ft.
Q = Cub. yd. per month (solids)	18,000·0 cub. yd.
G = Cub. yd. per hour (solids)	25·0 „
S = Cub. ft. per min. (solids)	55·5 cub. ft.
W = Cub. ft. per min. of water lifted (2—2 in. monitors at 65 lb. + 20 cub. ft. seepage = 120·9 × 2 + 20)	261·8 cub. ft.
T = Theoretical hp. (Pelton wheel 93·40 cub. ft. per min. at 500 ft. (effective head)	88·44 hp.
P = Brake hp. (at 75 % efficiency)	66·33 hp.

$$\text{Overall efficiency of plant} = \frac{\text{work done}}{\text{work applied}} = \frac{H\,(62{\cdot}3\,W + 100\,S)}{T \times 33000}$$

$$= \frac{H\,(62{\cdot}3\,W + 45\,G)}{T \times 33000}$$

$$= \frac{45{\cdot}7\,(62{\cdot}3 \times 261{\cdot}8 + 45 \times 25)}{88{\cdot}44 \times 33000}$$

$$= \frac{796785{\cdot}90}{2918520} = {\cdot}2730 = 27{\cdot}30\ \%$$

Mechanical efficiency of gravel pump including long belt drive (efficiency of Pelton wheel estimated at 75 %),

$$\text{M.E.} = \frac{27{\cdot}30}{75} = 36{\cdot}40\ \%.$$

In Table II the foregoing test has been tabulated with the test of the gravel pumping plant at King's Flat, Swaziland.

Comparative Tests of Hydraulic Elevators.

Table I.

	Swaziland.	Tekka, Ltd.
Height of lift	23·3 ft.	62·0 ft.
Solids, cub. yd. per month	17,570·0 cub. yd.	13,000·0 cub. yd.
,, cub. yd. per hour...	24·4 cub. yd.	18·05 cub. yd.
,, cub. ft. per min. ...	10·98 cub. ft.	8·12 cub. ft.
Monitor, nozzle diam.......	2·77 in.	2·0 in.
,, effective head ...	127·0 ft.	320·0 ft.
,, discharge, cub. ft. per min.	212·3 cub. ft.	177·0 cub. ft.
Seepage and extra water...	14·0 cub. ft.	—
Total monitor and seepage water lifted	226·3 cub. ft.	177·0 cub. ft.
Useful work done, ft. lb. per min.	354,078·0 ft. lb.	734,024·0 ft. lb.
Elevator, upraise pipe......	12·0 in.	12·0 in.
,, nozzle diam. in.	3·47 in.	2·5 in.
,, throat diam. in.	6·5 in.	5·0 in.
,, effective head ...	127·0 ft.	335·0 ft.
,, nozzle discharge, cub. ft. per min.	330·4 cub. ft.	282·5 cub. ft.
Ft. lb. per min. required for work	2,164,271·0	4,804,732·0
Efficiency....................	16·58 %	15·28 %
Proportion by weight, solids to water lifted ...	7·79 %	7·37 %
Proportion by weight, solids to water, including elevator water	3·17 %	2·84 %
Ratio of lift to effective head	1 : 5·45	1 : 5·40

Comparative Efficiency of Gravel Pumping Plants.

Table II.

	Swaziland.	Heawood Tin.
Height of lift	40·2 ft.	45·7 ft.
Solids lifted, cub. yd. per month	17,710·0 cub. yd.	18,000·0 cub. yd.
Solids lifted, cub. yd. per hour	24·6 cub. yd.	25·0 cub. yd.
Solids lifted, cub. ft. per min.	11·07 cub. ft.	11·25 cub. ft.
Water lifted, cub. ft. per min.	225·7 cub. ft.	261·8 cub. ft.
Work done in lifting solids and water, ft. lb. per min.	609,758·0 ft. lb.	796,785·7 ft. lb.
Power, electric units consumed	31·89 units	—
Power, theoretical power at Pelton jet	77·77 hp.*	88·44 hp.
Power, brake hp. consumed	42·75 bhp.	66·33 bhp.†
Ft. lb. per min. required for work	2,566,410·0 ft. lb.	2,918,520·0 ft. lb.
Mechanical efficiency of gravel pump	48·23 %	36·40 %‡
Overall efficiency of plant	23·76 %	27·30 %
Percentage by weight, solids to water lifted	7·87 %	6·90 %

* Estimating 45 % loss between Pelton jet and wattmeter on barge.

† Estimating efficiency of Pelton wheel, which was not running at the maximum speed, at 75 %.

‡ Including long belt drive.

General.—The foregoing figures show that a gravel pump driven with a belt by a Pelton wheel will have an efficiency of 27 %; when water power is converted into electricity the gravel pumping plant efficiency will be 23 %. At least 15 % efficiency may be expected from a hydraulic elevator.

The actual system installed will depend, among other things, upon the configuration of the ground and the quantity and situation of the water supply.

Monitors.—It would be interesting to know if monitors manufactured by the Pelton Wheel Co. have been tried in Swaziland, and if so what advantage Mr. West's monitor has over that type, which is used almost universally in this district.

Errors.—In the gravel pump formula (p. 20) 31·87 should be 31·89. On p. 12 the sluice box at Stable Creek is said to have a gradient of 1 : 30, in Appendix B this is given as 1 : 25.

In conclusion I wish to express my appreciation of Mr. Garrard's paper, which is a most complete description of a well arranged hydraulic mine. It cannot fail to be a most useful work of reference to hydraulic mining engineers. My thanks are due to Mr. A. H. Coombes for details of Heawood Tin Mine, and also to Messrs. Osborne & Chappel for allowing me to publish the results of the foregoing tests.

AUTHOR'S REPLY TO DISCUSSION

ON

'The Economic Geology of the Insizwa Range.'

By W. H. GOODCHILD, *Member*.

Mr. W. H. Goodchild: Dr. du Toit's remarks naturally demand first consideration owing to his intimate knowledge of the geology of the district, he, in fact, being the only one of my critics who has had the opportunity of studying the facts in the field upon which my interpretation of the phenomena is based.

Summarily, Dr. du Toit confirms my principal deductions bearing on the specific economic aspects of the occurrences, his confirmation of the distribution of the picrite differentiate and its origin by differentiation in place being in the most unequivocal terms. His point of difference as to the origin of the basin shape has no local economic significance, the basin shape being a matter of fact, not of theory. In its larger aspects, however, this origin of the basin shape is of interest to the general theory of economic geology. I do not wish to minimize the force of the arguments urged by Dr. du Toit against my conception as to the partially unconsolidated state of the sediments at the time of magmatic invasion. In a general sense their validity is beyond question.

There are, however, certain unusual factors that have to be considered in connection with these particular sediments, and it was these that led me to suggest a mode of origin of the basin shape and the other peculiarities of form and relationship presented by the intrusions, that would probably not apply to an ordinary marine mud buried under such a weight of material. Now, one of the most important essential differences between an unconsolidated mud and a shale is the almost de-hydrated character of the latter.

The question of 'sufficient time' urged by Dr. du Toit is beside the point if the local conditions have not during that particular time interval favoured de-hydration. The de-hydrating power of saline solutions and their power of coagulating colloids are among the commonplaces of chemistry. Per contra, the absence of its usual coagulating agents from a mud is a condition that entirely alters the whole complexion of the consolidation problem. Many muds appear to have been consolidated *without* the intervention of the pressures usually predicated as necessary; but, on the other hand, the coagulating power of electrolytes represents a force or system of forces of enormous magnitude. The particular sediments in which these basin-shaped intrusions occur happen to have been

deposited in water extraordinarily free from the electrolytes that commonly appear to play an important part in mud consolidation. These aspects of the problem seem to have escaped Dr. du Toit's notice, as well as that of Messrs. Crook and Morrow Campbell. The Karroo muds as a whole seem to have been consolidated by squeezing, and were consolidated at the time of igneous intrusion; but where an enormous area is squeezed, and the water is pressed out as from a sponge, there is no difficulty in conceiving limited areas into which water may have even been pressed in rather than pressed out, so that in the absence of the chemical de-hydrating coagulating factor there seems no greater difficulty in the way of a deep-seated porous clay than in the artesian conception of the water-logging of deeply-buried sandstones and similar sediments in certain special situations.

As I understand the problem the almost complete absence of sagging in the sense of a bending of the stratification is precisely what is to be expected by vertically compressing a more or less porous mass. The alternative hypothesis advanced by Dr. du Toit, namely: penetration along a curved crack, is merely begging the problem of the cause of curvature that it was my endeavour to solve. In the absence of any collateral evidence of how such conveniently situated and regularly curved cracks originated in strata that were undisturbed and, as Dr. du Toit says, 'have escaped tangential pressure,' the only kind of pressure likely to initiate such curved cracks, the Survey explanation is to my mind of a highly artificial and unconvincing nature.

I wish to take this opportunity of expressing my indebtedness to Dr. du Toit's fine work on the topography and general geology of the district. It formed the groundwork of my more detailed investigation of the economic aspects of the occurrence, which for various reasons he does not seem to have been in a position to examine with the thoroughness essential for the purposes of practical mining.

The point here raised goes to the root of our present system of State Geological Survey powers and organization. Dr. du Toit appears to have been debarred from collecting systematically much of that information that a mining engineer recognizes as essential to the effective understanding of the economic aspect of ore deposits. The author believes that it would be in the best interests both of the State and the mining industry if the State geological surveyors were allowed fuller scope for the collection of data. For these reasons, but certainly not in any sense of depreciation of Dr. du Toit's work, I cannot agree with Mr. Crook in his view that

the Survey monograph on the district can be accepted as a 'good account of the . . . economic geology of the Insizwa Range.' Such a view seems to me to illustrate an academic detachment from those intensely practical issues that are, or should be, implied in the qualification 'economic' to geologic studies.

Mr. Crook states that the theory of ore concentration by gravitative descent implies that the magma was injected in a homogeneous fluid state. This is not so, for a considerable degree of heterogeneity is obviously possible, and in this instance probable. As regards the 'warping' of the shale beds, which he says I assume, it was clearly stated both by Dr. du Toit and myself that the characteristic of the sills in the district is invasion without disturbance of the horizontality of the strata.

This also answers Mr. Morrow Campbell's query as to the variation in habit of occurrence from that described as laccolitic. The great and fundamental criterion of a laccolite, as distinguished from the phacolite and other injections of similar form, is that it is accompanied by folding of the encasing strata produced by the act of injection. This feature is absent, consequently the injections differ from laccolites on the most essential point in their definition, and Mr. Campbell's further reference to the convex form of the lower side of a laccolite has consequently no specific bearing on the problem of these peculiar undulatory sheets. The absence of anything 'like a regular increase in basicity towards the floor of the sill' that in Mr. Crook's view is 'too serious to favour the theory of differentiation from a magma injected in a homogeneous condition,' is one of the strongest pieces of evidence in favour of that theory as will be obvious to anybody who has ever watched and considered the settlement of a precipitate in a fluid bath ; moreover, one finds the complementary consolidated magma from which the olivine crystals were precipitated situated on top of the range and over the picrite, that is to say, precisely in the position to be expected if the differentiation were effected *in situ* by the sinking of the early-formed and heavy olivines in the fluid. Analytical and manufacturing chemistry would, I fear, be horrible and almost impossible operations in many instances if we could not get a better separation between a precipitate and a liquid than is implied in a 'continuous variation' in the composition and constitution of a partially fluid mixture.

While it may seem 'possible that the picrite may have been injected at a later stage than the main mass of the sill,' this is a most improbable theory, if one duly considers the positions of the norites, which Mr. Crook does not appear to have done. I agree

with Mr. Crook that the picrite layer might have been affected by movement during the later stages of consolidation. I go further, and produce evidence in my paper that it *was* moved to some extent in places, nor do I imagine that invasion and injection of the magma as a whole occurred in one short act, and that this is the meaning of the flow banding in the picrite 500 ft. above the base of the sill, my 'open admission' that seems to have somewhat disconcerted Mr. Crook, though I can assure him I have no admissions on the problems of the Insizwa geology that I do not desire to make just as openly if it will help to elucidate the truth. That the metamorphism of the sediments implies burial at some considerable depth I agree; at the same time it is worth pointing out that on the whole the metamorphism diminishes with depth, and is more pronounced at the upper surface of the sill, thus indicating that it is intervention of vapours rather than the pressure supposed by Mr. Crook that promotes the metamorphism.

Mr. Crook seems to have missed my points altogether in regard to the microgranites and the sulphide stringers. Fluxing of the sulphides in the sense he supposes is not part of the theory which I presented, but on the contrary the petrographic evidence goes to show that the sulphides were never 'unfluxed' so to speak, but were simply squeezed out in the fluid state from the mineralized zone into the closely adjacent contact fissures, one of the commonest and simplest operations in the whole range of magmatic mechanisms. Similarly, with the microgranites, wholesale melting of the hornstones certainly did not take place. Interstitial melting of some of the more easily fused constituents close to the contact during the period when the magma was exerting 'its full thermal effect' is the view I put forward, and this seems to be reasonable and quite in keeping with the current views of our leading petrologists as to the approximate equilibrium that must exist between solid rock and fused magma in the contact regions of those great intercrustal magma reservoirs that are supposed to furnish the supplies for igneous injections. Being acid these fluids would consolidate later than the gabbroid rock and would be very likely to be squeezed into contact fissures that were certainly formed at comparatively high temperatures.

Mr. Collins says 'he cannot understand' how acid micropegmatite could be a more fusible material than a basic rock such as gabbro. As Mr. Collins then proceeds to lay it down so emphatically that, 'It could not possibly be,' no arguments of mine seem likely to convince him. I would suggest to him, therefore, to study an ordinary textbook of geology where he will find how Nature

does the 'impossible,' and that his assertion directly traverses certain elementary and well established principles of geology.

Mr. Morrow Campbell says that a highly basic rock intruded slowly into a zone of acid sediments would 'undoubtedly assimilate much of the latter.' Most geologists who have studied basic injections into acid rocks seem to suffer from something more than doubts on this point. Dr. du Toit, for instance, says in this discussion that 'nowhere from over an immense region riddled with sills and dykes has any evidence been forthcoming of *any* assimilation of sediments by the Karroo dolerites or by the gabbros.' The basicity of a magma has little to do with its assimilating or with its metamorphic power. These seem to depend rather on the action of volatile substances that may or may not be present in a magma, than on the proportion of acid to base in the invading magma.

The points raised by Mr. Campbell *re* semi-diameter and photomicrographs are, I think, too trivial to warrant the use of much space to reply to in war time. This alleged 'importance' being to my mind somewhat imaginary. The latter was an oversight in proof reading, that is of particularly common occurrence in petrographic literature.

Prof. Cole agrees with me that there is no difficulty in accepting the view that the argillaceous rocks were by no means so compact at the time of igneous intrusion as my other critics insist. In connection with the acid flake-like veins he confesses he has nowhere seen evidence of flake-like veins formed by the infilling of shrinkage-fissures in an igneous mass near its margin.

Whether the fissures are to be considered as true shrinkage fissures is to my mind an open question, but these 'acid dykes' reminded me of the peculiar 'glauch' or barren veins at Nagyag, Transylvania, which appear to be inflows of slush with rock fragments from the encasing sediments. The parallelism with Insizwa in regard to the sediments and the basin-like form of the Nagyag intrusion, though it is wrongly represented as a broad pipe in most textbooks, as later work has shown, suggested to me that these dike-like masses might be a mimic of the more usual modes of occurrence and formation to which Prof. Cole evidently refers. An examination of the collateral evidence seemed to confirm this view, but as I too confess in my paper, I cannot regard the available evidence as conclusive for either hypothesis. I gladly accept Prof. Cole's timely correction in regard to the term 'hornfels.'

By all means let us relegate to oblivion such terms as 'hornfels,' 'grauwaeke,' and a host of others of much more modern origin, such

as 'rang,' 'subrang,' 'norm,' 'mineralography,' and the confusing army of terminological horrors that serve rather to hamper clear simple thinking than to advance natural knowledge.

The only extenuating circumstances I can plead for my use of the term hornfels is that my honoured tutor, the late Prof. Judd, used this term in days gone by, when we do not seem to have been so particular in asserting our peculiar national aptitude and preeminence as thinkers in the domain of geologic science.

In reply to Mr. Trewartha-James, there are no serious engineering difficulties in proving the deposits as, owing to their position in regard to the general topographical features of the district, adit driving, coupled with diamond drilling below the floor of the adits, solves the problem. My estimate of the expectation is set forth in the paper. Costs I am not at liberty to give beyond the general statement that they would be small in comparison with the expectation.

In reply to the President, the distance from the Insizwa to the nearest point in the Drackensburg is roughly 50 miles, but I am not sufficiently familiar with the Drackensburg to discuss its geological relations with the Insizwa. I think it very probable that the deposits of the Insizwa are by no means unique in this part of South Africa, and that to my mind is one of the important points from the economic side in connection with these researches whose particular object it was to assess the prospects of the occurrence of hidden ore deposits in the district: a kind of investigation that is unfortunately only rarely done scientifically, but one that makes specially exacting calls on the observational and deductive powers of the mining geologist. Whatever the Insizwa may be it is certainly a monumental example of how vast amounts of capital have been, and are continually being thrown away in the mining industry, in so-called 'practical prospecting' that could easily be conserved by taking advantage of modern geological methods of studying mineral occurrences.

Prof. Coleman, Prof. Gregory and Mr. Crook discuss the parallelism between the Insizwa deposits and those at Sudbury.

Prof. Coleman, who has such an intimate knowledge of the Sudbury deposits, is confident that my interpretation of the Insizwa as an example of ore accumulation by gravitative descent, is quite right. Prof. Gregory is equally confident it is quite wrong, and puts forward his own theory. Mr. Crook leans towards Prof. Coleman's view of the Sudbury deposits because he does not think the seemingly adverse evidence is sufficiently strong to overthrow it, though he has no positive explanation to offer of the

real significance of that evidence. Prof. Coleman staunchly reaffirms his view and states his reasons for rejecting the 'harmonizing' theory promulgated by Profs. C. F. Tolman and A. F. Rogers as the result of their recently conducted careful and illuminating microscopic studies.

I fully realized at the time my paper was written that, without a convincing solution of the Sudbury problem, the interpretation of the Insizwa I have given would be open to the same controversy, and in consequence its economic value and reliability as a weapon for assessing prospective values and guiding mining operations would be questioned.

In order to rectify this position I have since made a very careful study of the Sudbury occurrences, as set forth in the literature, particularly as regards the peculiar, and at first sight, disconnected array of facts that hitherto have not been satisfactorily explained. The Insizwa is a simpler affair as regards its details than Sudbury, and the evidence there in regard to the smelting hypothesis is of such a pronounced kind as to strike a metallurgist with irresistible force. The hypothesis not only explains the larger features, but many of the details, in so definite a way that it cannot be lightly disregarded as a practical working hypothesis and supplanted by such airy speculations as those promulgated by Prof. Gregory which, when it comes to the point of applying his theory to practical mining details, are so uselessly indefinite that they really explain nothing in particular.

Profs. Tolman and Rogers admit in their paper that they cannot explain the 'acid extracts' at Sudbury, which arise as an integral part of the ore-forming process. Let anyone examine their theory from the viewpoint of guiding mining operations underground and it will be found useless. Their supposed process cannot be definitely pictured in the mind, in itself a weighty objection to the theory, much less applied as a practical underground working hypothesis. Taking the Insizwa evidence and comparing it with the Sudbury, and noting the points of similarity and difference, led me to the preliminary conclusion that the matte smelting hypothesis was by far the most probable, but that the natural matte differed chemically in some way from the artificial products of the human metallurgist and so gave rise to a number of side reactions and physical effects during the consolidation process that nobody had hitherto been able to fathom.

Space will not permit me to give in any great detail the very complete solution of the Sudbury problem that I have worked out by applying physico-chemical methods of analysis to the geological

evidence. The bald outline of some of the more salient features may be summed up as follows:—When matte smelting is done under pressure in silicate melts containing small quantities of H_2O, such as the natural rock magmas, the matte which separates contains quantities of dissolved H_2S that vary in amount according to certain principles. In this respect, as well as in certain others, the matte differs from ordinary dry smelted artificial matte. On consolidation the sulphur of this dissolved H_2S is converted into metallic sulphide by reacting with iron oxide in the basic silicates in such a case as Sudbury. Thus some of the silicates are chemically broken up by the sulphide consolidation, and there is an *increase in volume* and quantity of the sulphides at the expense of silicates taking place after the main silicate consolidation, giving rise inevitably to silicate replacement. The hydrogen of the H_2S becomes oxidized to water by means of the oxygen liberated from the iron oxide on its conversion to pyrrhotite, thus giving rise to that local appearance of hydrothermal alteration, including hornblendization, that led the earlier investigators of the Sudbury occurrences to suppose that the ores had been introduced by aqueous solutions.

Abstracting base, FeO in the Sudbury instance, from basic silicates necessarily leaves acid residues, the so-called acid extracts. There are certain other expansions of the sulphides, the approximate magnitudes of which can be calculated so that this very definite and succinct physico-chemical explanation of the knotty points that have been urged so strongly against the smelting hypothesis not only confirms it, but explains also how it comes about that the matte is apt to be forced out of the eruptive into the adjoining country, a feature that is illustrated very clearly in the sulphide stringers at Insizwa and on a much grander scale in the offset deposits at Sudbury.

One result, therefore, of studying the economic geology of the Insizwa Range in a reasonably thorough way has been to effectually lay at rest one of the greatest and most perplexing controversies of modern economic geology.

I hope ere long to be able to publish a much fuller account of the physical chemistry and wider geological significance of the processes briefly outlined above.

Perhaps the most noteworthy and generally significant feature is that the difference between the Sudbury phenomena and those presented by ordinary matte smelting operations, as conducted by metallurgists, arises primarily from the presence of the small quantities of water that are present in Nature's slags, but are absent from the artificial slags of the smelter,

It is the little drop of water in the natural magmas that makes all the difference, on account of the various side reactions that it sets up. The solution of the Sudbury problem thus paves the way for the solution of a whole host of problems the world over, connected with the derivation of ore deposits from igneous magmas, which are the proximate sources of the great bulk of the world's metal supply. I have, therefore, followed up these preliminary researches with results of wide interest. It appears that *flotation of gassed matte,* followed by its 'self-bessemerization' in the adjoining country, is one of the most important combination of processes in the derivation of ore deposits from such acid magmas as granite; while in basic magmas the matte—which it is easy to show is not so highly gassed—gets carried down by the overwhelming swarm of sinking basic silicate crystals, as at Sudbury, Insizwa and elsewhere,

Now, iron is present in all rock magmas, and a metallurgist knows that all the ordinary common metals can be smelted out as sulphides on an iron matte basis as well as the noble metals gold and silver. The meaning of the common occurrence of pyrites, which is iron matte saturated with additional sulphur along with gold, silver, and the base metals in deposits derived from igneous magmas, comes into view, and there are strong chemical grounds for believing that in the case of lead and zinc these metals tend to get separated at the last from iron matte that originally collected them. Curiously enough, the deposits so concentrated in the magma generally present the appearance of having been formed by aqueous agencies or solutions, an illusion largely arising from the conversion of H_2S and other hydrogen compounds to H_2O in the manner so clearly illustrated at Sudbury. With certain modifications arising out of the specific differences between oxides and sulphides, it appears that oxide ore deposits of many metals are smelted out on similar lines.

A second result of these studies arising from an attempt to solve the Insizwa geological problems, and one of very wide interest, is therefore to throw light on the processes that have been operative in the formation of many deposits of iron, chrome, tin, titanium oxides, and possibly wolfram, as well as gold and silver deposits and those of the sulphides of copper, lead, zinc, etc., also tellurides, arsenites, etc. In general it may be stated that by supplementing the usual methods of geological research by these physico-chemical methods, the economic value of the microscopic investigation of ore deposits is enormously increased, for by its aid one can read off, so to speak, the chemistry of what has been taking place at any

particular point in an ore deposit, and so by taking a sufficient number of observations, get an analysis of its history in detail just as sampling and assaying enable one to estimate the variations and average metallic contents of the ores.

Lastly, by this complete solution of the Insizwa problem it appears more probable than ever that the expectation of enrichment in depth of the mineralized zone is well founded.

Insizwa thus stands as probably the best mining prospect for a really serious supply of platinum at present known within the precincts of the British Empire, a metal for which we are almost entirely dependent on foreign sources of supply.

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